MEDICAL AND VETERINARY ENTOMOLOGY

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MEDICAL AND VETERINARY ENTOMOLOGY

A TEXTBOOK FOR USE IN SCHOOLS AND COLLEGES
AS WELL AS A HANDBOOK FOR THE USE OF
PHYSICIANS, VETERINARIANS AND
PUBLIC HEALTH OFFICIALS

BY

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Dedicated to
MY STUDENTS IN PARASITOLOGY

PREFACE TO SECOND EDITION

The author owes a debt of gratitude to the many readers of the first edition for the cordial reception accorded to it, a reception which makes possible this new edition.

The rapid growth of literature dealing with insects and related organisms, as they affect the public health and animal industry, has made it necessary to rewrite most of the subject matter in order to keep it largely within its original limits. An historical account of the development of Medical Entomology has been added and many of the chapters have been enriched by the experience of the author as a Sanitary Officer in the United States Army during the late war. Many new illustrations have been added and a few old ones have been replaced. Those who have used the first edition will find the new edition practically a new book and if the second edition of *Medical and Veterinary Entomology* receives the same wide use and general approval as the first edition, the author will feel amply repaid for the arduous labor involved in its preparation.

W. B. H.

BERKELEY, CALIFORNIA.

PREFACE

Much of the matter contained in the following pages was prepared for the press more than six years ago, but owing to the rapid advances made in the field of parasitology, particularly concerning insects, the writer has withheld it until this time, when, after considerable revision and addition, it has seemed expedient to publish the same. The manuscript has been in almost constant use for a period of six years in teaching classes in parasitology, both in the University of California and in the San Francisco Veterinary College. It has been the aim to include herewith a large part of the writer's original work, some of which has until now remained unpublished, as well as the published observations of many other investigators in this field, all of which has gone to build up the foundation of the new science of *Medical Entomology*.

This book is not intended to be a comprehensive treatise, touching all the investigations in the field of medical entomology, but rather an attempt to systematize the subject and to assist in securing for it a place among the applied biological sciences. However, a discussion is included of all of the more important diseases and irritations of man and of the domesticated animals in which insects and arachnids are concerned, either as carriers or as causative organisms.

Owing to the immense literature on insects as relating to disease, much of which is widely scattered, the student in this field must spend considerable time in searching for the desired information, and what is more important, the information is not readily accessible to the physician, the veterinarian, the health officer and the sanitarian. It is therefore to be hoped that this book will not only prove useful as a text, but also as a handbook for all individuals who are professionally interested in the health and well-being of man and beast, as affected by insects and arachnids.

In the second place detailed accounts of experiments are included here and there, so that the investigator might employ the methods described in either the repetition of the work or in carrying on further investigations along the lines suggested.

Although many special papers have been consulted in the preparation of this work, a bibliography is not included herewith, inasmuch as this information is obtainable in much more complete form in the bibliographical works of other writers. Reference to special papers is usually made in footnote form, but where certain facts have long been accepted as common knowledge, reference is ordinarily omitted.

Sources from which assistance has been drawn are too numerous to adequately enumerate, but to all who have contributed toward the preparation of this work I wish to express my sincere appreciation and thanks, but most particularly to my advanced students in parasitology, who have contributed much valuable data, and to my colleagues, Professor C. W. Woodworth, Dr. Edwin C. Van Dyke, Dr. W. A. Sawyer, and Mr. S. B. Freeborn, and to my wife, Lillie M. Herms, who have at all times given generous coöperation and kindly criticism.

Unless otherwise credited the illustrations are from photographs and drawings made by the author and various assistants. Thanks are due particularly to Dr. William Colby Rucker for the use of flea drawings, to Professor Herbert Osborn for permission to reproduce certain drawings of biting and sucking lice, to M. B. Mitzmain for photographs of *Tabanas striatus,* to Prof. J. S. Hine for photographs of certain other Tabanids, and to Mr. W. C. Matthews, Scientific Illustrator, for valuable assistance in the preparation of many of the figures.

W. B. H.

Berkeley, California.

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MEDICAL AND VETERINARY ENTOMOLOGY

CHAPTER I

INTRODUCTION

Historical.—Whether the term "flies" as used in the Old Testament (Exodus 8, 24) is coextensive with its modern use may be questioned, but it is interesting to study the significance of the following passage, "and there came a grievous swarm of flies into the house of Pharaoh, and into his servants' houses, and into all the land of Egypt: the land was corrupted by reason of the swarm of flies." As early as 1577 Mercurialis [1] expressed the belief that flies carried the virus of plague from those ill or dead of plague to the food of the well. Although we now know that this is not the usual mode of plague transmission, the principal part that flies play as disease vectors in general was correctly interpreted.

In 1587 Gabriel Soares de Souza [2] stated that flies suck poisons from sores (*Frambœsia tropica*) and leave them in abrasions on healthy individuals, thus infecting many persons. In 1769 Edward Bancroft [3] advanced a similar theory, but it was not until 1907 that Castellani [4] demonstrated experimentally that flies do transmit *Treponema pertenue* (Castellani) the causal agent. The house fly as a real menace to health was, however, hardly appreciated until 1898 when Veeder [5] wrote:

> "I have made cultures of bacteria from fly tracks and from the excrement of flies and there seems to be not the slightest difficulty in so doing. Indeed the evidence of every sort is so clear that I have reached the conclusion that the conveyance of infection in the manner indicated is the chief factor in decimating the army. Certainly so far as is known to the writer, nothing adequate has been said about it in current discussions."

Although popular beliefs in parts of Europe, Asia and Africa had for many years connected mosquitoes with various tropical fevers, no well formulated ideas were advanced until 1848 when Josiah Nott[1] of New Orleans published his belief that mosquitoes gave rise to both malaria and yellow fever. In 1854 Daniel Beauperthuy[2] a French physician in the West Indies formulated an excellent theory that mosquitoes were responsible for the transmission of yellow fever, believing, however, that the disease factor was carried from decomposing matter and introduced into the human by the insect.

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[1] Mercurialis (Hieronymus), 1577 (?) De pestes in universum, præsertim vero de Veneta et Patavina. Item de morbis cutaneis, et omnibus humani corporis excrementis. (Not available to author.)

[2] De Souza, Gabriel Soares, 1587. Tratado descriptivo do Brazil em 1587, obra de Gabriel de Souza. Typographia universal de Laemmert. Rio de Janiero. 120 pp. (Cited by França, C. in Trans. R. Soc. Trop. Med. and Hyg. London. Vol. xv, Nos. 1-2.)

[3] Bancroft, Edward, 1769. An Essay on the Natural History of Guiana in So. America. T. Becker and P. A. De Houdt. London. 402 pp.

[4] Castellani, Aldo, 1907. Experimental Investigation on *Frambœsia tropica* (Yaws). Journ. of Hygiene, Vol. vii, pp. 558-599.

[5] Veeder, M. A., 1898. Flies as spreaders of sickness in camps. Medical Record, Vol. 54, No. 12, pp. 429-430.

While considerable was known by early naturalists and physicians concerning the larger intestinal parasites, such as round worms and tapeworms, little information relating to microörganisms was available until after the development of the microscope by Anton van Leeuwenhoek[3] (1632-1723). His discovery that his "material contained many tiny animals which moved about in a most amusing fashion; the largest of these showed the liveliest and most active motion, moving through the water or saliva as a fish of prey darts through the sea," led to the study of hitherto invisible organisms and eventually to the discovery of microscopic disease producing parasites, as fully expressed by Pasteur[4] in 1877 in his "germ theory."

Although according to Howard[5] no standard medical treatise mentioned any specific insect-borne disease prior to 1871, Raimbert[6] showed in 1869 by experiment (inoculation of proboscides, wings, etc., of non-biting muscids into guinea pigs) that anthrax (*Bacillus anthracis* Davaine) could be disseminated by flies, which was believed to be the case as early as 1776 by Montfils.[7] The first discovery, however, of primary importance in the field of medical entomology was made in 1878 when Patrick Manson[8] working in China observed the development of *Filaria bancrofti* Cobbold in the body of a mosquito, *Culex fatigans* Wied. (probably *Culex quinquefasciatus* Say) and eventually together with Bancroft, Low and others he proved the mosquito to be the intermediary host and vector of the causative organism of filariasis.

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[1] Nott, Josiah C., 1848. On the origin of yellow fever. New Orleans Med. and Surg. Journ., Vol. IV, pp. 563-601.

[2] Beauperthuy, L. D., 1854. (Transmission of yellow fever and other diseases by mosquito.) Gazeta oficial de Cumanà, Año. 4, No. 57, May 23. (Cited by Howard, Dyar and Knab.)

[3] Leeuwenhoek, Anton van, 1695. Arcana naturæ detecta ope microscopiorum. Delphis Batavorum, Kronevelt. 568 pp. (Cited by Howard, Dyar and Knab.) See also, The select works of Antony van Leeuwenhoek, translated by Samuel Hoole, London, 1798.

[4] Pasteur et Joubert, 1877. Chimie Physiologique:—Étude sur la maladie charbonneuse. Compt. Rendus de l'Acad. des Sci., T. 84, No. 18, pp. 900-906.

[5] Howard, L. O., 1921. Sketch History of Medical Entomology. A Half Century of Public Health, edited by Ravenel. Amer. Pub. Health Assoc., New York, pp. 412-438.

[6] Raimbert, A., 1869. Recherchés experimentales sur la transmission du charbon par les mouches. Compt. Rendus de l'Acad. des Sci., T. 69, pp. 805-812. (Cited by Nuttall.)

[7] Montfils, A. J., 1776. D'une maladie fréquente connue en Bourgogne sous le nom de Puce maligne. Journal de médecine, Vol. XLV, p. 500. (Cited by Nuttall.)

[8] Manson, Patrick, 1878. On the development of *Filaria sanguinus hominis*, and on the mosquito considered as a nurse. Journ. Linn. Soc., London. (Zool.) (75), Vol. 14, Aug. 31, pp. 304-311. (Cited by W. D. Pierce.)

The discovery by C. L. A. Laveran[1] in 1880 of the causative organism of malaria (*Plasmodium malariæ* Laveran) as an inhabitant of the red blood cells of man, marks an epoch in protozoölogy. Taking rank with Laveran's discovery of the malaria parasite is the discovery by Theobald Smith[2] in 1889 of the causative organism (*Babesia bigeminum* Smith and Kilbourne) of Texas cattle fever, also a red blood corpuscle inhabiting protozoön. Associated with Smith in the investigation of the disease was F. L. Kilbourne,[2] and together in 1893 they made the second great fundamental discovery in the field of medical entomology, namely that the cattle tick, *Boöphilus annulatus* (Say), is the necessary intermediary host of the causal agent of the disease. Thus in connection with Manson's discovery concerning mosquitoes and filariasis, a new basis for the control and prevention of disease in both man and domestic animals was established.

In quick succession there followed a series of famous discoveries. In 1895 Bruce[3] investigated Nagana, the fatal tsetse-fly disease of Africa (Zululand) and discovered the causative organism, *Trypanosoma brucei* Plimmer and Bradford, in the blood of infected animals and established the fact that the parasite is conveyed from animal to animal through the agency of *Glossina morsitans* Westwood.

In 1898 Ronald Ross[4] announced to the world his discovery that certain "dapple-winged mosquitoes" (Anophelines) are the carriers of malaria. In this discovery there are linked the names of Ross, Manson,[5] Bastianelli,[6] Bignami, Grassi, Sambon and Low,[7] the last two in 1900 having demonstrated beyond a doubt the fact of transmission. In the same year (1898) Simond[8] succeeded in transmitting plague from a sick rat to a healthy rat through the agency of infected fleas.

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[1] Laveran, A., 1880. Note sur un noveau parasite trouvé dans le sang de plusieurs malades atteints de fievre palustre. Bull. de l'Acad. de med., Paris, Vol. 9, p. 1235. (Cited by Howard, Dyar and Knab.

[2] Smith, Theobald and Kilbourne, F. L., 1893. Investigations into the nature causation and prevention of Texas or Southern Cattle Fever, Bull. No. 1. Bur. An. Ind., U. S. Dept. of Agric., Washington, D. C., 301 pp.

[3] Bruce, David, 1895. Tsetse-fly disease or Nagana in Zululand. Preliminary Report (Bennett and Davis, Field St. Durban), Dec., 1895. (Cited by Nuttall.)

[4] Ross, R., 1898. Pigmented cells in mosquitoes. British Med. Journ., Feb. 26, pp. 550-551.

[5] Manson, P., 1898. Surgeon-Major Ronald Ross. Recent Investigations on Mosquito-Malaria Theory. British Med. Journ., June 18, pp. 1575-1577.

[6] Bastianelli, G., Bignami, A. E., Grassi, B., 1898. Coltivazione delle semilune malariche dell'nomo nell *Anopheles claviger* Fabr. Nota preliminare. Real. Accad. dei Lincei, Nov. 28. (Cited by Nuttall.)

[7] Sambon, L. W., and Low, G., 1900. The malaria experiments in the Campagna. British Med. Journ., Vol. 2, pp. 1679-1682.

[8] Simond, P., 1898. La propagation de la peste. Ann. de l'Inst. Pasteur, Vol. XII, p. 625.

This latter discovery was at first discredited, but the experiments were successfully repeated by Verjbitski[1] in 1903 and Liston[2] in 1904.

One of the world's outstanding achievements is that of the United States Army Yellow Fever Commission, consisting of Reed,[3] Carrol, Lazear and Agramonte, which in 1900 on the island of Cuba proved beyond doubt that yellow fever is carried by a mosquito, *Aedes argenteus* Poirret (then known as *Culex fasciatus* and later as *Stegomyia calopus*). Carlos Finlay,[4] a Cuban physician, had as early as 1880 propounded the theory and conducted experiments in an attempt to prove his theory, hence amply deserves recognition and great praise. Unlike malaria the causal agent of yellow fever was not discovered until nearly twenty years after the vector became known, i.e., although the insect carrier was discovered in 1900, it was not until 1919 that Noguchi[5] working in Ecuador proved *Leptospira icteroides* Noguchi to be the pathogenic agent.

In 1901 Forde[6] observed certain parasites in the blood of Gambian Sleeping Sickness patients, which Dutton recognized as trypanosomes and named them *Trypanosoma gambiense* Dutton, and in 1903 Bruce and Nabarro[7] showed that *Glossina palpalis* Robineau-Desvoidy was the carrier, thus adding another tsetse-fly disease to our list. Stephens and Fantham[8] in 1910 described *Trypanosoma rhodesiense* as the causative organism of Rhodesian Sleeping Sickness and Kinghorn and Yorke[9] in 1912 proved *Glossina morsitans* Westwood to be the responsible vector.

Dengue or breakbone fever, a widely distributed disease of the tropics and subtropics, was found to be a mosquito borne disease by Graham[10] while working in Syria in 1902. Graham and later Ashburn and Craig[1] showed that several species of mosquitoes, such as *Culex quinquefasciatus* Say and *Aedes argenteus* Poirret are able to transmit the disease. A very closely related disease and apparently one of equal importance is pappataci fever, also known as three-day fever, or sand-fly fever, of which *Phlebotomus papatasii* Scopoli has been shown to be the vector by Doerr, Franz and Taussig[2] in 1909. As in dengue the causative organism of pappataci fever is still unknown.

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[1] Verjbitski, D. T., 1908. The part played by insects in the epidemiology of plague. Journ. of Hyg., Vol. VIII, p. 162.

[2] Liston, W. G., 1905. Plague rats and fleas. Journ. Bombay Nat. Hist. Soc., Vol. XVI, pp. 253-273.

[3] Reed, Walter, 1900. The etiology of yellow fever. Philadelphia Med. Journ., Oct. 27, 1900, Vol. VI, pp. 790-796.

[4] Finlay, Carlos J., 1881 *et seq.* Trabajos selectos. Republica de Cuba. Secretaria de Sanidad y Beneficencia. Havana, 1912, xxxiv + 657 pp. (Cited by Riley and Johannsen.)

[5] Noguchi, H., 1919. Etiology of yellow fever. Journ. Exp. Medicine, Vol. XXX, No. 1, pp. 1-29.

[6] Forde, R. M., 1902. Some clinical notes on a European patient in whose blood a trypanosoma was observed. Journ. Trop. Med., Vol. V, p. 261.

[7] Bruce, D., and Nabarro, D., 1903. Progress report on sleeping sickness in Uganda. Reports Sleeping Sickness Comm. of Roy. Soc., No. 1.

[8] Stephens, J. W. W., and Fantham, H. B., 1910. Trans. Soc. Trop. Med. and Hyg., Vol. VI, pp. 131-142.

[9] Kinghorn, A., and Yorke, W., 1912. On the transmission of human trypanosomes by *Glossina morsitans*, Westw., and on the occurrence of human trypanosomes in game. Ann. Trop. Med. and Para, Vol. VI, No. 1, pp. 1-23.

[10] Graham, Harris, 1902. Dengue: A study of its mode of propagation and pathology. Med. Record, Vol. lxi, pp. 204-207.

In 1903, fowl spirochætosis caused by *Spiroschaudinnia* (*Spirochœta*) *marchouxi* Nuttall was proved to be tick borne by Marchoux and Salimbeni,[3] who showed *Argus persicus* Oken the common fowl tick to be a vector. Another tick borne disease came to light when Dutton and Todd[4] and Ross and Milne[5] in 1904 discovered that African relapsing fever is carried by the tick, *Ornithodorus moubata* (Murray) Pocock, the causative organism being *Spiroschaudinnia* (*Spirochœta*) *duttoni* (Novy and Knapp). Furthermore, in 1906 Ricketts,[6] working in Montana (U. S. A.), proved conclusively that a tick, *Dermacentor venustus* Banks = (*Dermacentor andersoni Stiles*), is the vector of Rocky Mountain spotted fever of which Wolbach[7] (1919) considers *Dermacentroxenus rickettsi* to be the causative organism.

Although lice have for centuries been associated with filth and disease, apparently little thought was given these insects as possible carriers of disease, although Melnikoff[8] in 1869 had shown that the biting dog louse, *Trichodectes latus* Nitzsch, was an intermediary host of the double-pored tapeworm, *Dipylidium caninum* (L.), which occasionally occurs in humans. In 1879 Aubert,[9] according to Nuttall, considered that pediculi caused impetigo, prurigo, pityriasis, etc., and in experiments carried out by Dewevre[10] in 1892 lice were shown to carry the specific microörganisms on their front legs and infection was produced in healthy persons. Furthermore, Flügge[1] in 1891 and Tictin[2] in 1897 both supposed that disease might be carried by vermin and the latter carried on experiments with bedbugs. In 1907 Mackie[3] working in India found that Asiatic Relapsing Fever was transmitted by the body louse, *Pediculus capitis* De Geer, in whose body the causative organism *Spiroschaudinnia* (*Spirochæta*) *carteri* (Mackie) multiplies.

---

[1] Ashburn, P. M., and Craig, C. F., 1907. Experimental investigations regarding the etiology of dengue fever. Journ. Infectious Diseases, Vol. 4, pp. 440-475.

[2] Doerr, R., Franz, K., and Taussig, S., 1909. Das Pappatacifieber. Leipsig & Wien. Franz Deutiche. 166 pp.

[3] Marchoux, E., and Salimbeni, A., 1903. La spirillose des poules. Ann. l'Inst. Pasteur, Vol. XVII, pp. 569-580.

[4] Dutton, J. E., and Todd, J. L., 1905. The nature of human tick fever in the eastern part of the Congo Free State, with notes on the distribution and bionomics of the tick. Liverpool School of Trop. Med., Memoir XVII, 18 pp.

[5] Ross, R. H., and Milne, A. D., 1904. Tick fever. British Med. Journ., Vol. II, pp. 1453-1454.

[6] Ricketts, H. T., 1906. The transmission of Rocky Mountain spotted fever, by the bite of the wood tick (*Dermacentor occidentalis*). Journ. Amer. Med. Assoc., Vol. lvii, p. 358.

[7] Wolbach, S. B., 1919. Studies on Rocky Mountain spotted fever. Journ. Med. Research, Vol. 41, No. 1, pp. 1-193.

[8] Melnikoff, H., 1869. Ueber die Jugendzustände der Tæma cucumerina. Arch. f. Naturgesch., XXV, Th. 1, pp. 62-69.

[9] Aubert, 1879. Les poux et les écoles. Un point d'hygiene scolaire. Reviewed in Annales de Dermatologie, 1880, 2, s., I, p. 292. (Cited by Nuttall.)

[10] Dewevre, 1892. Note sur le rôle des pediculi dans la propagation de l'impetigo. Compt. rend. de la soc. de biol., Paris, No. 11, pp. 232-234. (Cited by Nuttall.)

It was not, however, until 1909 that Nicolle, Comte and Conseil[4] working in Tunis and Ricketts and Wilder[5] in 1910 working independently in Mexico proved experimentally that the body louse (*Pediculus corporis* De Geer) was a carrier of typhus fever, the causative organism of which *Rickettsia prowazeki*) was described and named by Da Rocha-Lima[6] in 1916.

Members of the insect family Reduviidæ (cone noses or kissing bugs) have long been known for their fierce bites and bloodthirstiness, but it was apparently not until 1909 that insects of this group were experimentally proved to be disease carriers. In that year Chagas,[7] who had already described the causative organism *Schizotrypanum cruzi* Chagas of Chagas Disease known as Brazilian trypanosomiasis or parasitic thyroiditis, demonstrated that this disease was carried by the reduviid, *Triatoma megista* Burmeister.

Flies of the family Tabanidæ (horseflies, gad flies, earflies, deerflies, etc.) as already observed were looked upon with suspicion as early as 1776, but apparently no satisfactory evidence was forthcoming until 1913, when Mitzmain[8] (Mayne) working in the Philippine Islands demonstrated the transmission of Surra through the agency of *Tabanus striatus* Fabr. which he regards as the principal carrier. Strong evidence against Tabanid flies of the genus Chrysops as intermediary hosts of *Filaria loa* (Cobbold) was discovered by Leiper[9] also in 1913.

[1] Flügge, C., 1891. Grundriss der Hygiene. (Cited by Nuttall.)

[2] Tictin, J., 1897. Zur Lehre von Rückfalltyphus. Centralbl. f. Bakteriol. I Abt., XXI, pp. 179-186. (Cited by Nuttall.)

[3] Mackie, F. P., 1907. The part played by *Pediculus corporis* in the transmission of relapsing fever. British Med. Journ., p. 1706.

[4] Nicolle, Charles, Comte, C., et Conseil, E., 1909. Transmission experimentale du typhus exanthimatique par le pou du corps, Paris Acad. Sc. Comptes Rendus, T. 149, pp. 486-489.

[5] Ricketts, H. T., and Wilder, R. M., 1910. The transmission of the typhus fever of Mexico (Tarbardillo) by means of the louse (*Pediculus vestimenti*). Journ. Amer. Med. Assoc., Vol. 54, No. 16, pp. 1304-1307.

[6] Da Rocha-Lima, H., 1916. Untersuchungen über Flechfieber. Münch. Med. Wochenschrift, Vol. 63, No. 39, pp. 1381-1384.

[7] Chagas, C., 1909. Ueber eine neue Trypanosomiasis des Menschen. Memorias do Instituto Oswaldo Cruz, I, pp. 159-218.

[8] Mitzmain, M. B., 1913. The mechanical transmission of surra by *Tabanus striatus* Fabr. Philippine Journ. of Science, Vol. VIII, No. 3, Sec. B., pp. 223-229.

[9] Leiper, Robert T., 1913. Metamorphosis of *Filaria loa*. London Lancet, Jan. 4, p. 51.

Tularæmia also known as Pahvant Valley Plague (Utah, U. S. A.) or Deerfly fever was shown by Francis and Mayne[1] in 1921 to be carried from rodent to rodent by the Tabanid fly *Chrysops discalis* Williston, and presumably from rodent to man in the same manner. The causative organism of this disease, *Bacterium tularense*, was described in 1911 by McCoy as the cause of a plague-like disease of California ground squirrels.

Both historically and for future investigation the relation, which the protozoön subfamily Herpetomoninæ of Castellani and Chalmers bears to insects and their relation to animal and plant diseases, is one of great interest to parasitologists. Numerous insects are known to harbor Leptomonas (inclusive of Herpetomonas), Crithidia, Leishmania and other genera of doubtful classification, but the problem of segregating those which are zoö-and phytopathogenic from those which are merely entomoparasitic is exceedingly difficult and fraught with snares and pitfalls. Apparently the earliest discovery in this connection concerning plants was made by Lafont[2] in 1910 when he demonstrated that *Leptomonas davidi* Lafont, the cause of "flagellosis" in three species of Euphorbiaceæ, required as its intermediary host the bug, *Nysius euphorbiæ* Horvath.

In 1900 Leishman described an organism which he believed to be the cause of kala azar, or tropical splenomegaly, again described by Donovan in 1903 and named *Leishmania donovani* (Laveran and Mesnil). As early as 1907 Patton[3] secured evidence that the bedbug, *Cimex rotundatus* Signoret (-*C. hemipterus* Fabr.) was a vector of the disease, a matter still held in some doubt although Adie[4] working in Assam reports in 1922 the finding of *Leishmania donovani* in the salivary glands and ducts of *Cimex rotundatus*, thus apparently establishing the fact that the bedbug is able to transmit kala-azar by its bite.

Scope.—The foregoing historical outline will, no doubt, give the student a better understanding of the scope of the subject under consideration. When the term, medical entomology,[5] first came into use about 1909 to designate a more or less well defined field of endeavor, there were many who ridiculed our enthusiasm and minimized the importance of insects and arachnids as vectors of disease. Today this subject takes rank with many of the older branches in the study of public health and medicine, both human and veterinary.

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[1] Francis, Edward, and Mayne, Bruce, 1921. Experimental transmission of tularæmia by flies of the species *Chrysops discalis*. U. S. Public Health Service Reports, Vol. 36, No. 30, pp. 1738-1746.

[2] Lafont, A., 1910. Sur la presence d'un Leptomonas parasite de la classe des Flagellés dans de latex de trois Euphorbiacées. Ann. l'Inst. Pasteur, Vol. 24, pp. 205-209.

[3] Patton, W. S., 1907. Preliminary report on the development of the Leishman-Donovan body in the bedbug. Sci. Mem., Med. and Sanitary Dept. Gov't. of India, 28, pp. 1-19.

[4] Adie, H. A., 1922. Kala-azar inquiry of the Indian Research Fund Association. Indian Journ. Med. Res., Calcutta, Vol. IX, No. 3.

[5] Herms, W. B., 1909. Medical Entomology, its scope and methods. Journ. of Econ. Ento., Vol. 2, No. 4, pp. 265-268.

Medical entomology, therefore, may be defined as the science which deals with insects and arachnids (and related organisms) as causative agents or vectors of disease and their control. It becomes evident that a specialist in medical and veterinary entomology must be well fortified in the studies of zoölogy, chemistry, bacteriology and epidemiology, and in addition must have a strong specialized training in entomology, parasitology and pathology. Hence the student of mosquitoes and malaria should be thoroughly familiar with the taxonomy, ecology and anatomy of mosquitoes, and, as the causative organism of malaria is blood inhabiting, a knowledge of blood and blood methods is essential, and he must have careful training in protozoölogy. I furthermore believe that his training is incomplete until he is thoroughly familiar with methods of control, so that he will be able, if necessary, to intelligently take charge of a malaria control campaign. This does not imply that the medical entomologist should do all the work himself, and as an example of one of the most successful malaria control campaigns in California I would cite the Anderson[1] campaign, which was in charge of a trained medical entomologist under whose direction there worked a physician, a diagnostician, a microscopist, a trained nurse, and a gang of workmen carrying out his directions as to drainage.

The aim of medical entomology is the control and prevention of insect borne diseases, and many notable examples of the service rendered by workers in this fertile field, will occur to the student without much trouble, such as the malaria and yellow-fever mosquito campaigns of Cuba and the Panama Canal Zone,[2] and the heroic campaign[3] against rats and fleas in San Francisco in 1907 which resulted in the eradication of plague from that city and prevented its spread to other parts of the United States.

Control of Insect-Borne Diseases.—The control of insect-borne diseases involves not only the control of the responsible insect vectors, but also the protection or control of the focus or source from which the insect receives its infection. Thus in the simplest form of insect transmission of disease by mechanically contaminating or infecting food and drink, the source of infection may be found in the unsanitary disposal of human excreta and other dangerous animal wastes, and therefore the possibility of spread by insects may be largely overcome by correcting the defect in sanitation. The use of properly constructed fly-tight privies or septic tanks in the country will largely prevent the spread of typhoid fever and related diseases by flies; the use of paper sputum cups (cups to be protected from flies and burned) helps to prevent the possible spread of tuberculosis by flies, etc. The rigid enforcement of anti-spitting laws and ordinances regulating the disposal of excreta are necessary in this connection. Rodent control is intended to destroy the natural reservoir of plague, the flea being only an agent in the dissemination of the causative organism, *Bacillus pestis,* from rodent to rodent and rodent to man.

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[1] Freeborn, Stanley B., 1920. Malaria control; a report of demonstration studies at Anderson, California. California State Board of Health Monthly Bulletin, Vol. 15, No. 9, pp. 279-288.

[2] Le Prince, Joseph A., and Orenstein, A. G., 1916. Mosquito control in Panama, the eradication of malaria and yellow fever in Cuba and Panama. G. P. Putnam's, 355 pp.

[3] Eradicating plague from San Francisco,—report of Citizens Health Committee. Prepared by F. M. Todd; C. A. Murdock Co. Press, San Francisco, 313 pages, May 31, 1909.

Furthermore, the handling of infectious cases is a matter of great importance, as for example the screening of yellow-fever cases during a certain stage in the course of the disease, against the mosquito carrier. Properly screening malaria patients against mosquitoes is also a factor in malaria control. Searching out and treating certain ambulatory cases (carriers), notably sterilization of malaria cases by cinchonization, while offering many obstacles should not be overlooked in a program of disease control even though insects are the sole vectors. Experience in this field, however, has proved that insect control is the safest and surest method.

Insect Control.—In the control of disease-transmitting insects, the most vulnerable point in the life history is sought, and the most effective combative methods are then applied. This involves an intimate knowledge of life history and habits. The more familiar we are with regard to these two factors, the better equipped are we to cope with the problems of control.

The application of control measures may be either of a temporary or permanent nature. Temporary control involves the elimination of a nuisance for a short time, a few hours or a few days, requiring constant repetition; for example, the use of formaldehyd to kill flies, or pennyroyal or citronella to repel mosquitoes, or even oil as applied to mosquito-breeding pools. Permanent control, on the other hand, involves the elimination of breeding places, or permanent protection of the same by mechanical means, to prevent the deposition of insect eggs, for example, draining or filling up unnecessary ponds and pools of standing water, in which mosquitoes may breed; or placing horse manure and general refuse in receptacles made fly-tight in order to forestall the breeding of house flies.

Permanent control measures, when feasible, will always be less expensive in the end, and also very much more effective than the use of temporary agents in the form of insecticides, which must be applied repeatedly, with continuous expenditure of time, labor and money. Standing water can often be drained off with little expense, whereas the repeated application of oil must eventually involve greater outlay and inconvenience. To illustrate, the writer at one time observed a small pond which was surely furnishing most of the mosquitoes for the neighborhood; it was the only pond near, and was within ten feet of a rapidly running stream lower in elevation than the pond by at least eighteen inches. This pond could have been drained very easily and would have resulted in permanent prevention; however, oil was being applied regularly. The pool was evidently of no use to any one, and was within the limits of a mosquito campaign. Again, the common house fly, a source of so much annoyance, is ordinarily combated with poisons, sticky fly paper and screens, when the mere removal of perhaps a single horse manure pile in the immediate vicinity would speedily give ready and permanent relief.

In the practical control of insects observations made in the field are indispensable to the correct interpretation of laboratory or clinical observations.

Vital Losses Due to Insects.—Comparisons between agricultural and vital losses occasioned by insects, while interesting, are by their very nature inaccurate and confusing. However, the United States Department of Agriculture estimates the annual agricultural loss occasioned by insects in the United States at about $800,000,000 and Hunter[1] in 1913 estimated the annual vital losses (human and animal) attributed to insects at about $358,000,000 with the following comment:

> "The two branches are radically different in one important respect. One deals with material losses and the other with a reduction in the vital force of a nation. Is it right to compare the loss of a human life with the loss of 28 bales of cotton or 1,700 bushels of corn? The loss in cotton or wheat might be made good in another region or during another season, but for the life that is lost there is no compensation."

Of the above total vital loss it is estimated that $100,000,000 is traceable to malaria and $100,000,000 to Texas cattle fever, both of which are wholly insect and arachnid borne. Losses to the animal industries can be much more carefully estimated, but losses in human efficiency and life cannot be so easily arrived at. Furthermore, Carter[2] has well said concerning malaria,

> "It is not in its death rate that the gravest injury of malaria lies; it is its sickness rate, in the loss of efficiency it causes rather than in the loss of life. One death from pneumonia ordinarily corresponds to about 125 sick days,—work days lost; one death from typhoid fever to 450 to 500 sick days; one from tuberculosis to somewhat more than this among whites. A death from malaria, however, corresponds to from 2,000 to 4,000 sick days. This loss of efficiency may really be doubled or trebled, for the man infected with malaria is frequently half sick all of the time. The loss of efficiency caused

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[1] Hunter, W. D., 1913. American interest in medical entomology. Journ. of Econ. Ento., Vol. 6, No. 1, pp. 27-39.

[2] Carter, H. R., 1919. The malaria problem of the South. U. S. Public Health Reports, Vol. 34, No. 34, pp. 1927-1935.

by malaria in the country of the malarious section is beyond comparison greater than that caused by any other disease, or even by any two or three diseases combined, including typhoid fever and tuberculosis."

How Much to Spend on Control.—The farmer can estimate fairly closely what he can afford to spend, on the control of insects affecting his crops, and it occurred to the author[1] that the vital losses based on "work days lost" might offer a basis on which to proceed in estimating reasonable outlays for insect control in the present connection, of which the following is an example.

"In 1918 there were 5,887 deaths from tuberculosis in California, amounting to a loss of (5,887 x 500) 2,944,500 work days; there were 187 deaths from typhoid, amounting to a loss of (187 x 450) 84,150 work days; and 56 deaths from malaria, with a loss of (56 x 3,000) 168,000 work days; a total loss to California of about 3,200,000 work days. In control work against typhoid fever the State spent between $35,000 and $50,000 in 1918. Assuming that this amount was justified, for such it actually was, because there was a reduction of about 12 per cent in the typhoid rate for 1919, there should have been expended in malaria control between $70,000 and $100,000 because the total number of work days lost is double that of typhoid fever. As a matter of fact, the State spent about $5,000 in malaria control in 1918 and the malaria death rate went up from 1.5 per 100,000 in 1917 to 1.8 in 1918, an increase of about 20 per cent. In the matter of tuberculosis control on the typhoid basis the State should have spent about $1,750,000 in 1918, which was closely approximated, the actual amount being $1,673,000."

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[1] Herms, W. B., 1919. What shall we do with our information concerning malaria in California? California State Board of Health Monthly Bull., Vol. 15, No. 6, pp. 181-189.

CHAPTER II

PARASITES AND PARASITISM

Definition.—A *parasite* may be defined as an organism that lives on or in another living organism (the *host*) with a more or less harmful result to the latter. There are many degrees of *symbiosis*, i.e., living together of dissimilar organisms, each organism being known as a *symbiont*. The relationship may be one of *benefit* to both (reciprocal) and may be termed *mutualism*, e.g., the tiny beetles, *Xenodusa* (*Atemeles*) *cava* (Lec.) and *Xenodoxus montana* Csy., secrete a fluid which ants (*Formica rufa* and others) suck from glandular hairs and in return for this service the ants feed the beetles which are said to be unable to feed themselves and perish if unassisted by the ants. Also the corn root aphis (*Aphis maidiradicis* Forbes) is cared for in a most solicitous fashion, from egg to adult, by several species of ants (*Lasius*), which feed on the so-called honey-dew of the aphis.

When only one of the two organisms is profited by the symbiosis the relationship is known as *commensalism*, e.g., a minute species of cockroach, *Attaphila fungicola*, is said by Wheeler to lick the surfaces, feeding on oily secretions of *Atta* ants, which tolerate the little roaches "without the slightest signs of hostility." No harm of course results to the ants and evidently no benefit is derived by them.

When the symbiosis reaches the stage when one of the symbionts secures an advantage with *harmful* results to the other, a degree of *parasitism* is obtained. *Parasitism*, therefore, involves the process of one organism (the parasite) gaining nourishment or advantage at the expense of another living organism (the host), which latter should not be destroyed as the result of this condition before at least the developmental period of the former is completed, otherwise the result might prove disastrous to both the parasite and the host.

The student should clearly distinguish between the parasitic habit and the *predaceous* habit among insects. Thus insects which capture their prey and suck their juices or eat their bodies usually killing the same either outright or quickly, are said to be predaceous, e.g., members of the family Reduviidæ, also known as cone noses or assassin bugs, and the lady beetles of the family Coccinellidæ.

Furthermore, flesh fly maggots, which are normally *scavengers*, feeding on dead flesh, readily attack living animals if suitable points of entrance to the body are obtained; this is particularly true of the screw worm fly, *Cochliomyia macellaria* Fabr.

Classes of Parasites.—Animal parasites are known as *zoöparasites,* while *phytoparasites* include those which belong to the plant kingdom. Parasites which live either temporarily or permanently on the outside of the body are termed *ectoparasites.* Animals of this group are known as *ectozoa,* e.g., the lice; parasites which live within the host are called *endoparasites,* the animals being called *entozoa,* e.g., tapeworms. *Obligatory* parasites are obliged to remain for their entire life history in or on the body of the host, of which there may be two, primary and secondary, otherwise the parasite must perish, e.g., both the biting and sucking lice. *Facultative* parasites may also be free living and change readily from one host species to another, e.g., mosquitoes. Mosquitoes are also examples of *intermittent* parasites which prey upon the host at times only, being free living during the interval.

Many other forms of parasitism are recognized, e.g., *transitory* parasitism is said to refer to such cases in which the organism is parasitic during only a part of its life history when it is an obligatory parasite, e.g., bot flies. When two hosts are required for the development of the parasite, that host in which the parasite reaches sexual maturity is termed the *primary* or *definitive* host, while the other is referred to as the *secondary* host; this is illustrated in the life history of the malaria parasite (*Plasmodium*) which reaches sexual maturity in the body of certain anopheline mosquitoes, which are the primary or definitive hosts, while the human being is the secondary host.

Effect of Parasitism on the Host.—The study of parasitism has contributed much during the past few years to the field of pathology and clinical medicine, the disturbances resulting from parasitism being usually of a specific nature, and causes of certain symptoms heretofore unknown are now often readily accounted for on this basis. Chandler[1] has well stated:

> "In fact it may be said that a very large number of diseases or abnormal conditions which were once attributed to purely physical causes, such as imperfections in the organization of the body, which have been accepted merely as common derangements of the human machine for which no direct cause could be found, have been traced to the effect of parasites located, perhaps in some unsuspected part of the body."

There are probably nearly as many ways in which parasites affect the host as there are species of parasites, but a few general classes of injury may be suggested; (1) mechanical injury due for example to insect bites; (2) simple skin irritations as caused by biting lice (Mallophaga); (3) injection of so-called poisons as in certain tick bites; (4) obstruction of certain internal organs as may be the case in horse bots; (5) tissue feeding by maggots; (6) anaphylactic reactions; etc.

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[1] Chandler, Asa C., 1918. Animal parasites and human disease. John Wiley & Sons, New York, xiii + 570 pp.

Effect of Parasitism on the Parasite.—All parasites are more or less specialized in the direction of their habits, e.g., fleas are laterally compressed, to effect ease of motion between hairs; while lice are provided with strong clasping organs by means of which they hold fast to hairs; both of these examples are wingless and have sacrificed much of the ordinary means of locomotion. Endoparasites are usually provided with specialized hooks, barbs, suckers, etc., for purposes of attachment to the alimentary canal or other organs, e.g., the botfly larvæ, the flukes (Trematoda), the tapeworms (Cestoda), etc. Perhaps, because of the ease with which food is secured, the sense organs are usually not strongly developed; the eyes may be very simple or wanting. The mouth parts differ in the several groups, depending on the particular habits of the parasite. It is interesting to note that the parasitic habit has often apparently resulted in the development of structural similarity. This is particularly apparent in the clasping structures of the biting and sucking lice, which belong systematically to two different orders; namely, the Mallophaga and the Anoplura respectively.

Although the parasite itself is usually situated in a protected environment on or within the host, its progeny are usually exposed to many dangers in the process of finding a new host, hence the great fertility of parasites in general is a striking characteristic. The fertility is apparently more or less proportional to the hazards of life.

Origin of Parasitism.—Modern parasites are restricted more or less completely to particular host animals, which necessitates the deduction that the parasite must have developed its habit after the existence of the host, and in consequence parasitism must be a recently acquired habit on the part of a one-time free-living organism. This becomes more apparent by a study of the life history of the parasite; invariably the earlier stages point to a primitively free-living existence. Perhaps the ancestors of a given group of modern parasites were attracted to the waste food, offal and exudations of certain animals; the search for food having become simplified, they began living as messmates, or commensalists, or as scavengers; the association between the two species became closer and eventually the line of parasitism was completed. This is also borne out by a study of the nearest allies of a given parasite, in which the gradation from the free-living animal to the parasite may be traced. The very close structural similarity between the free-living, wingless book louse, *Troctes divinatoria* Mull. (a member of the order Corrodentia, family Psocidæ) and a common hen louse, *Menopon biseriatum* Piaget (a member of the order Mallophaga), leads us to believe that the parasitic Mallophaga have been derived directly from the Psocidæ. Knowing the habits of the book louse, we can easily imagine how the line of parasitism might eventually have become established; i.e., from the eating of feathers, skins and excretions off the animal to the eating of the same on the animal as a host is not difficult to imagine at least.

Degrees of parasitism may also be illustrated by examples from the biting lice (Mallophaga), in which there are species having the power to run freely and live for a considerable length of time off the host, e.g., *Menopon pallidum* Nitzsch., the common hen louse, while other related species have become quite sessile, as in the extreme case of the wormlike louse (*Menopon titan* Piaget), inhabiting the gular pouch of the pelican. Among the fleas there are also good examples of gradation in habit and structure, e.g., the human flea (*Pulex irritans* Linn.), which has developed remarkable springing power and is comparatively free to move from place to place, while the mature female hen flea (*Echidnophaga gallinacea* Westw.) is usually quite sessile, holding fast to one spot much like a tick.

The medical entomologist is continually beset with questions concerning the early development of the present intimate relation existing between insects and causative organisms of disease. It is interesting to know that Galli-Valerio[1] has recently found that *Herpetomonas pyrrhocoris* Zotta et Galli-Valerio lives part of the time in flagellate form in the rotting blossoms of the meadow saffron (*Colchicum autumnale*), where it is picked up apparently by the bug in the spring and is deposited in non-flagellate form again in the blossom during the autumn by means of the insect's excreta. This is believed to be a very primitive degree of the adaption of a saprophytic protozoön to an internal parasitic life in an insect. The relationship existing between *Herpetomonas davidi*, already referred to, living in the latex of *Euphorbia* and carried by the bug. *Nysius euphorbiæ*, represents a step in advance.

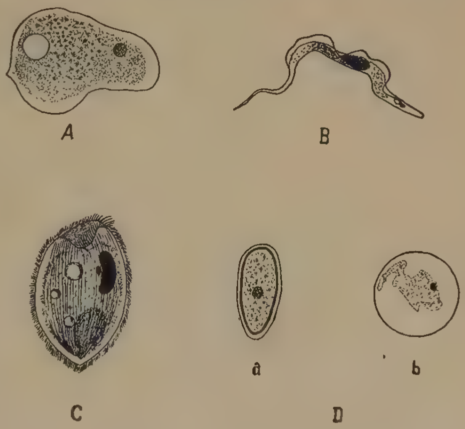

FIG. 1.—Types of Protozoa. A. Sarcodina, represented by *Entamœba histolytica* of Amœbic Dysentery; B. Mastigophora, represented by *Trypanosoma gambiense* of African Sleeping Sickness; C. Infusoria, represented by *Balantidium coli,* causative organism of a certain oriental dysentery (redrawn after Leuckart); D. Sporozoa, represented by (*a*) *Coccidium oviforme* from liver of rabbit, (*b*) *Plasmodium vivax* of Malaria shown in a red blood corpuscle. (All greatly enlarged.)

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[1] Galli-Valerio, B., 1920. Le Cycle evolutif probable de l'*Herpetomonas pyrrhocoris,* Zotta & Galli-Valerio, Schweiz. Med. Wochenschr., 1, 1920, pp. 401-402. (Cited in The Review of Applied Entomology, Medical and Veterinary, Vol. X, Ser. B, Part 1, p. 8, Jan., 1922.)

Systematic Position of Animal Parasites.—Though parasitic animals are found in other phyla, those of economic importance affecting man and beast are included almost exclusively in the following:

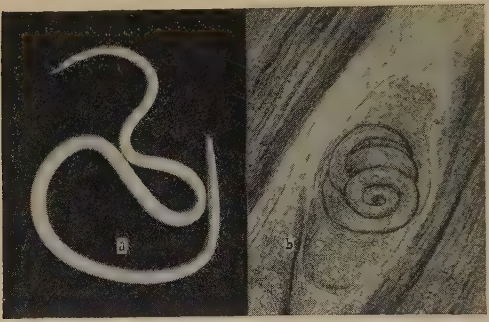

FIG. 2.—Examples of parasitic round worms (Phylum Nemathelminthes, Class Nematoda). *a.* Round worm of swine (*Ascaris lumbricoides*); *b.* *Trichinella spiralis,* greatly enlarged.

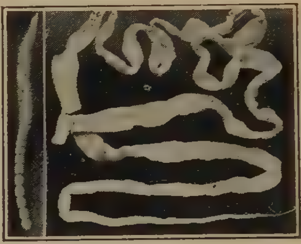

FIG. 3.—Examples of parasitic flat worms (Phylum Platyhelminthes, Class Cestoda.) A poultry tape worm (*Choanotænia infundibuliformis* × 1) on the left; and a common tape worm of cattle (*Tænia expansa,* greatly reduced) on the right.

a. Protozoa,—unicellular animals (Fig. 1); e.g., *Entamœba histolytica* Schaudinn, causing amœbic dysentery; *Plasmodium vivax* Grassi and Feletti, causing malaria; *Trypanosoma gambiense* Dutton, causing African sleeping sickness.

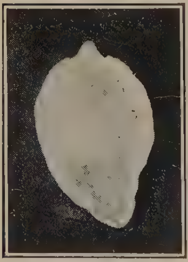

FIG. 4.—Example of parasitic flat worms (Phylum Platyhelminthes, Class Trematoda). A liver fluke of sheep and cattle (*Fasciola hepatica*) × 1.

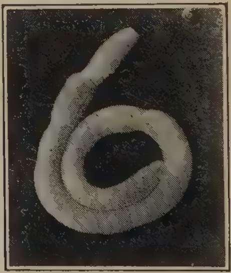

FIG. 5.—Example of segmented cylindrical worms (Phylum Annelida, Class Chætopoda). Earthworm (*Lumbricus sp.,* × .5) non-parasitic, but may serve as an intermediary host for certain poultry tapeworms.

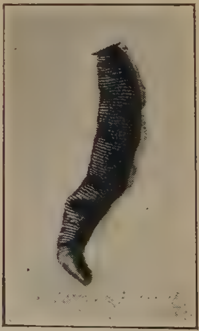

FIG. 6.—Example of segmented cylindrical worms (Phylum Annelida, Class Hirudinea). Leech (*Hirudo medicinalis*) × .5.

b. Nemathelminthes,—bilateral, unsegmented worms of cylindrical form (Fig. 2); e.g., *Trichinella spiralis* Owen, causing trichinosis; *Ascaris lumbricoides* Linn., roundworm of man; *Ankylostoma duodenale* Dubini, a hookworm of man. Development is commonly direct.

c. Platyhelminthes,—bilateral worms; flattened dorsoventrally; no anal opening. Usually requiring an intermediate host.

1. *Cestoda,*—head or scolex with separable segments called proglottides (Fig. 3); e.g., *Tænia solium* Linn., the pork tapeworm of man; *Tænia saginata* Goeze, the beef tapeworm of man; *Dipylidium caninum* (Linn.), a common tapeworm of the dog.
2. *Trematoda,*—alimentary canal branched; mouth in a sucker; e.g., *Fasciola hepatica* Linn., the sheep liver fluke (Fig. 4).

d. *Annelida,*—bilaterally symmetrical, segmented or annulated worms.
  1. *Chætopoda,*—locomotor chætæ; segmentation extending to internal organs, e.g., *Lumbricus terrestris* Linn., a common earthworm (non-parasitic) (Fig. 5).
  2. *Hirudinea,*—flattened; sucker at each end of body; arrangement of internal organs does not correspond to external segmentation; e.g., *Hirudo medicinalis* Linn., the medicinal leech (Fig. 6).

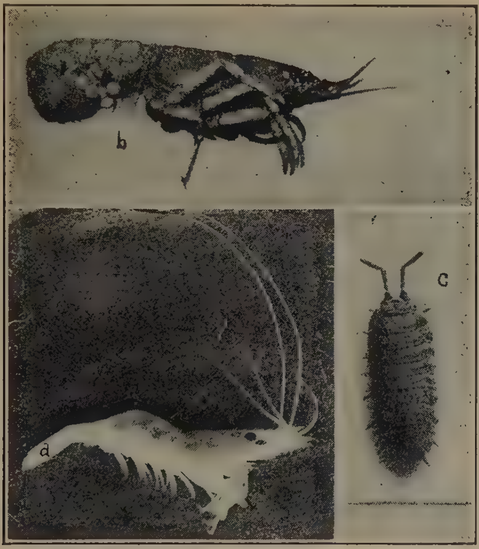

FIG. 7.—Examples of the Phylum Arthropoda, Class Crustacea. *a.* Shrimp × 1.2; *b.* Crayfish × .6; *c.* Sowbug × 2. (All three examples are non-parasitic.)

e. *Arthropoda,*—segmented body with jointed appendages; exoskeleton; bilateral symmetry; ventral nerve-cord;
  1. *Crustacea,*—aquatic; gill respiration; two pairs of antennæ; biramous appendages; e.g., the shrimp, the crayfish and the sow bug. (These examples are non-parasitic.) (Fig. 7.)
  2. *Protracheata,*—elongate, wormlike, segmented body; paired, unsegmented appendages; one pair of antennæ; tracheal respiration; elongate dorsal heart; e.g., *Peripatus* (Fig. 8) (non-parasitic).
  3. *Myriapoda,*—body elongate and wormlike; each segment except first two and last one bearing one pair of jointed walking appendages, *Centipedes,* some of which are venomous (Fig. 9*a*); or two pairs, *Millipedes* (Fig. 9*b*).

4. *Insecta,*—body divided into three divisions (head, thorax and abdomen); three pairs of walking appendages on thorax; two pairs of wings on thorax (may be reduced or absent); one pair of antennæ; compound eyes; usually three simple eyes; tracheated respiratory system; e.g., *Triatoma protracta* (Uhler) (cone-nose); *Cimex lectularius* Linn. (bedbug); *Anopheles maculipennis* Meig. (malaria mosquito); etc. (Fig. 10).

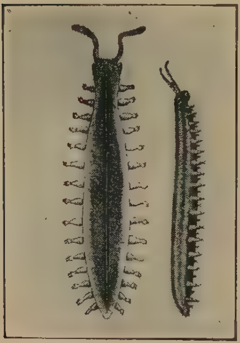
FIG. 8.—Example of the Phylum Arthropoda, Class Protracheata. Peripatus (after Folsom) × .5.

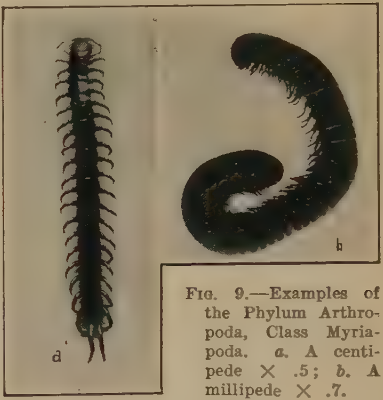

FIG. 9.—Examples of the Phylum Arthropoda, Class Myriapoda. *a.* A centipede × .5; *b.* A millipede × .7.

5. *Arachnida,*—head and thorax fused to form cephalothorax; four pairs of walking appendages on cephalothorax (larvæ may be hexapod); wingless; no antennæ; eyes simple, when present; e.g., *Latrodectes mactans* Fabr., a poisonous spider; *Hadrurus hirsutus* Wood, scorpion; *Margaropus annulatus* Say, the Texas fever tick; *Dermanyssus gallinæ* Redi, the poultry mite; *Psoroptes communis* Fürst., the scab mite. (Fig. 11.)

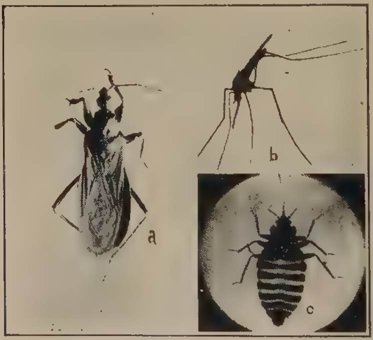

FIG. 10.—Examples of the Class Insecta. *a.* A Reduviid (cone nose) × 1.5; *b.* A mosquito (Anopheles) × 3; *c.* Bedbug (Cimex) × 2.5.

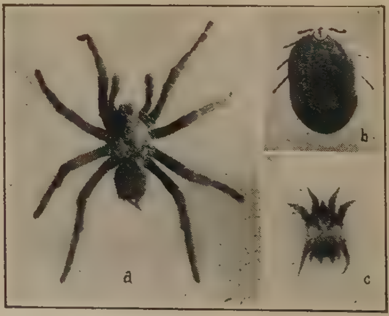

FIG. 11.—Examples of the Phylum Arthropoda, Class Arachnida. *a.* A spider × .5; *b.* A tick × 1.3; *c.* A mite × 30.

CHAPTER III

INSECT ANATOMY AND CLASSIFICATION

The Insecta (Fig. 10) are essentially segmented animals, the primitive number of segments being probably nineteen or twenty, based on ontological evidence. This number is no longer evident, owing to the specialization of the head and posterior terminal segments. The most striking condition is the separation of the body into three divisions; the *head* bearing the antennæ, mouth parts and eyes; the *thorax* possessing the locomotor appendages, usually two pairs of wings and three pairs of legs; the *abdomen*, bearing no appendages except the terminal organs of sexual prehension in the male, or ovipositor in the female. The respiratory system of the insect consists of a complex series of tubes (Fig. 12) ramifying all parts of the body, carrying air from the outside through the spiracles segmentally arranged on both sides of the thorax and abdomen.

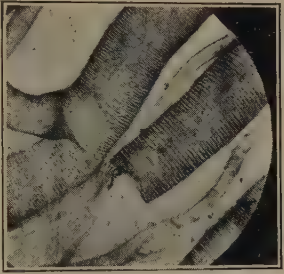

FIG. 12.—A few tracheal tubules taken from an insect. (Greatly enlarged.)

Insect Larvæ.—When insect larvæ, parasitic or accidental, are encountered in the body of man or beast, there may be some difficulty in classifying them readily, with the result that they may be incorrectly placed among the worms, for example, bots and warbles (Œstridæ), or screw worms and other flesh fly larvæ in cases of myiasis. Usually these larvæ (Fig. 13) are short and plump, ordinarily possessing eleven or twelve well-marked segments. Furthermore, microscopic examination will reveal a system of minute tubules (Fig. 12), the tracheal breathing system, ramifying all internal parts of the body, even the minutest portions between muscle fibers. This system is not present in worms.

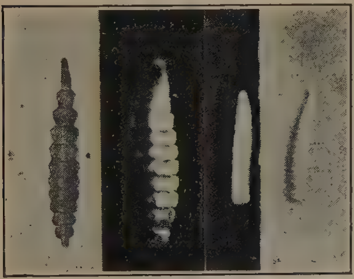

FIG. 13.—Insect larvæ,—showing typical external segmentation. × 1.

The larvæ of Dipterous insects (flies) are commonly called "maggots" and are footless; the larvæ of Coleoptera (beetles) are called "grubs," and have three pairs of feeble legs; the larvæ of Lepidoptera (moths and butterflies) have never less than four pairs of legs including prolegs and are known as "caterpillars"; Neuropterous larvæ (dobson flies, etc.) are not easily distinguished, but the presence of three pairs of legs with more than twelve body segments, including the head, will serve to distinguish these in at least many cases.

Importance of Knowing Internal Anatomy.—It is important that the student familiarize himself with the internal anatomy of the insect, with special reference to the digestive system and its accessory structures, such as the salivary glands. Two cases will point out this necessity:

1. The simplest condition in which the internal organs of insects are concerned in disease transmission is in the case of the house fly, in which pathogenic organisms may be sucked up with dejecta and passed out with the feces of the fly, and deposited on human food, either in their original virulent condition or more or less attenuated or weakened.

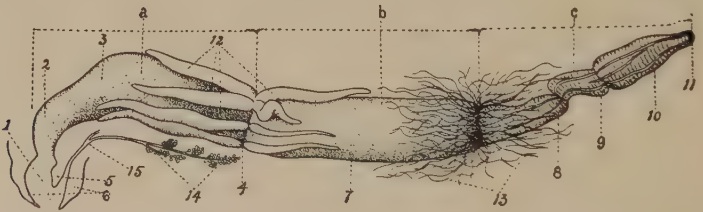

FIG. 14.—Drawing of a typical insectan alimentary tract. *a.* fore-gut; *b.* mid-gut; *c.* hind-gut; 1. pharynx; 2. œsophagus; 3. crop; 4. gizzard; 5. hypopharynx; 6. mandibles; 7. stomach; 8. ileum; 9. colon; 10, rectum; 11. anus; 12. gastric cæca; 13. Malpighian (excretory) tubules; 14. salivary gland; 15. salivary duct. × 2. (Adapted after Folsom.)

2. The more complicated condition is in the case of the Anopheles mosquito, which sucks up pathogenic organisms (malaria parasites) with the human blood, and these undergo very important and vital sexual changes within the body of the insect, eventually finding lodgment in the salivary glands of the same before introduction by the "bite" into the next human victim,—thus the insect is an essential intermediary host.

Digestive System.—There are three distinct regions to the insect intestine (Fig. 14); namely, (1) the *fore-gut,* consisting of the mouth, pharynx, esophagus and proventriculus; (2) the *mid-gut,* consisting of the stomach; and (3) the *hind-gut,* consisting of the ileum, colon, rectum and anus. The proventriculus presents merely a widened portion of the esophagus in the more generalized forms and serves as a food receptacle. In the more specialized groups, such as the Diptera and Lepidoptera, the crop is expanded into a capacious pocket or pouch. In such forms in which the *gizzard* is present this organ consists of a highly muscular dilation provided internally with chitinous teeth for grinding food; for example, the grasshopper. The stomach is a simple sac into which open the *gastric cœca,* generally few in number, which give rise to certain digestive fluids. At both ends of the stomach are located valves which direct the flow of the food. There is much variation in the length and degree of convolution of the hind intestine, but usually the three regions mentioned, namely, ileum, colon and rectum, may be located. Emptying into the ileum are the excretory or *Malpighian tubules* varying in number and length in the various groups of insects.

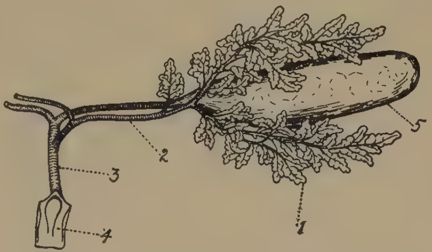

Fig. 15.—Salivary system (right side) of an insect,—a cockroach. 1. Salivary glands; 2. Salivary duct; 3. Common salivary duct; 4. Hypopharynx; 5. Reservoir. (Adapted after Miall and Denny.)

The salivary system consists of a pair of salivary glands (Fig. 15) which may be lobed, situated within the head, often extending into the thorax. Usually each gland empties into a *salivary duct,* the two ducts joining into a common duct which opens into the esophagus or pharynx. In many species of insects there is present a pair of *salivary reservoirs;* these may be located near the opening of the common duct and then present a compound condition, or may be situated on either side of the esophagus at the end of a long slender duct.

Insect Classification.—The medical entomologist must be equipped with a good knowledge of the basic principles of classification, so as to be able to correctly place the insect at hand in its proper order and family at least, and in the case of parasitic insects should be able to run the specimen to the species with the aid of a key. To determine the *Order* to which an insect belongs one need usually only know the character and structure of the wings if present and the type of the mouth parts. This will enable the student to place at least ninety per cent of the commoner insects in their proper *Orders.* Unfortunately the parasitic forms have undergone many changes such as reduction or loss of the wings, and great modification in form, but generally the mouth parts will serve as a ready means for rough identification. Before passing on to a list of the Orders of insects, the usual basis for classification will be considered here, viz.:

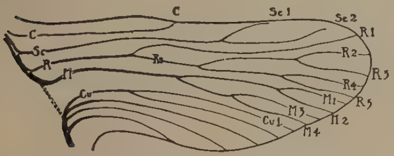

Fig. 16.—Hypothetical type of wing venation. *A.* anal vein; *C.* costa; *Cu.* cubitus; *M.* media; *R.* radius; *Sc.* subcosta. (Redrawn from Folsom, after Comstock and Needham.)

1. Wings,—(*a*) presence or absence of, (*b*) form, (*c*) structure.

2. Mouth parts,—(*a*) biting (mandibulate), (*b*) sucking (haustellate).

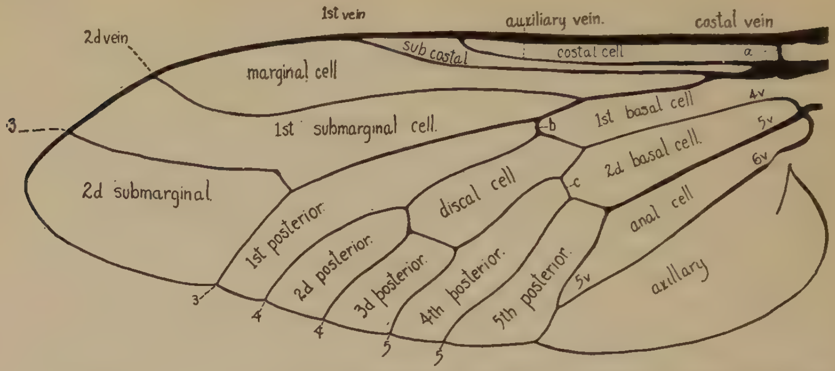

FIG. 17.—Wing of an insect (Tabanus), to illustrate terminology as applied to venation and cells.

3. Metamorphosis,—(*a*) primitive, (*b*) simple (incomplete), (*c*) complex (complete).

Wings.—The earliest systems of insect classification were based on wing characters, which together with the mouth parts offer a basis for the more modern arrangement also. The venation of insect wings is so markedly characteristic for each species that even a part of a wing is often all that is necessary for determination. There are typically two pairs of wings present, situated on the mesothorax and metathorax, though in many parasitic insects, such as the bedbugs, lice, fleas, certain louse flies, etc., the wings are absent. Wingless insects such as those mentioned should not be included with the *Aptera,* which is an order of *primitively* wingless insects. The parasitic wingless insects fall under several different orders, as will be seen. To avert confusion it is therefore probably better to dispense with the term *Aptera* and substitute the term *Thysanura* as used by a number of entomologists.

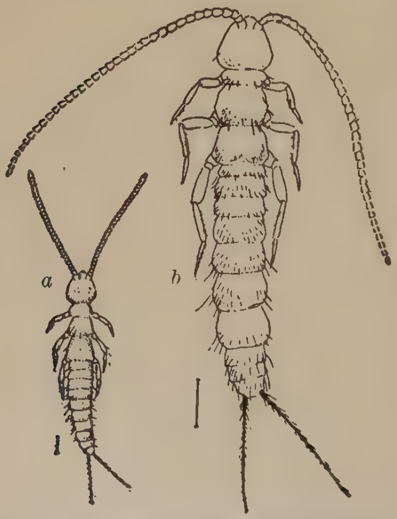

FIG. 18.—Illustrating primitive metamorphosis. *a.* young of a Thysanuran insect (Campodea); *b.* adult of the same. (After Kellogg.)

In form the wing presents a more or less triangular appearance. Generally the fore and hind wings differ considerably in size; the fore wing in some groups, such as the May flies, many butterflies and moths, and the bees and wasps, is larger than the hind wing, while in the grasshoppers, cockroaches, beetles, etc., the fore wing is narrow and serves largely as a cover (elytron) to the hind wing, which folds fanlike. Again, in the dragon flies, white ants and ant lions, the fore and hind wings are nearly equal. In the flies, the hind pair of wings is replaced by club-shaped organs known as *halteres,* leaving consequently only one pair of wings, hence the name Diptera (two-winged).

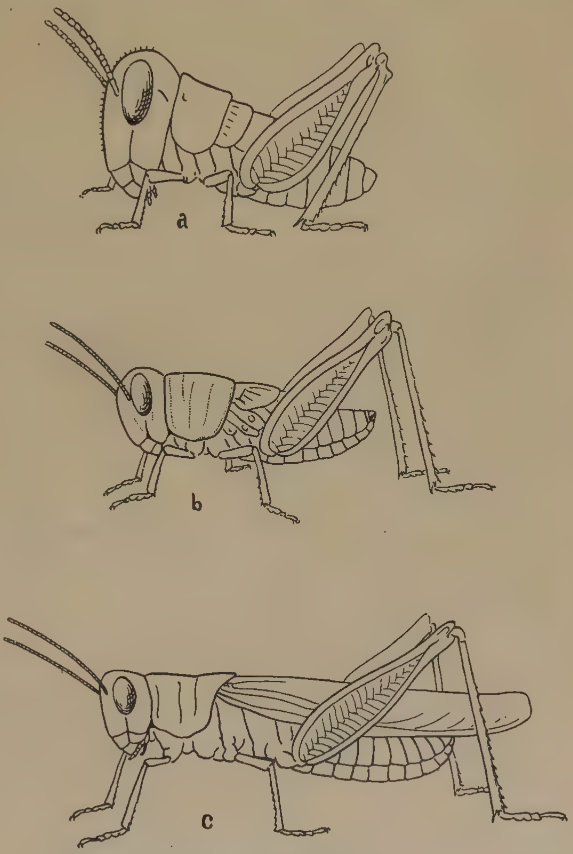

Fig. 19.—Illustrating simple metamorphosis. *a.* Young wingless grasshopper; *b.* Showing wing pads after the first molt; *c.* Adult of the same. (Redrawn after Packard.)

There is also a great variation in structure of the wings, though for each order a certain general condition prevails; e.g., the Neuroptera have thin membranous wings, often quite filmy; however, Diptera and many Hemiptera have the same texture, but possessing fewer wing veins and a different venation. The Diptera can, of course, be readily distinguished by the presence of but a single pair of wings. The typical Hemiptera have the front wings thickened at the base, while the apical portion is membranous (Hemiptera-Heteroptera). The other division of this order has a pair of entirely membranous wings (Hemiptera-Homoptera).

The venation of the insect wing, as has been mentioned, is an important factor in classification on account of the great variety of arrangement, and the reliability of this character for identification of the family and species. By a careful study of the evidence, a fundamental type of wing venation has been constructed by Comstock and Needham. The figure (Fig. 16) illustrating this type will be useful in determining the identity of the principal veins. The spaces between the veins are called *cells,* shown in Fig. 17, which figure also illustrates the use of the numerical system of nomenclature.

Metamorphosis.—In order to attain to the size and development of the parent the young insect undergoes greater or less change in size, form and structure, which series of changes is termed *metamorphosis.* The least change is found in the Thysanura (Aptera), which are primitively wingless, and hence the newly emerged young individual is externally unlike the parent only in size,—this type of metamorphosis is termed *primitive* (Fig. 18).

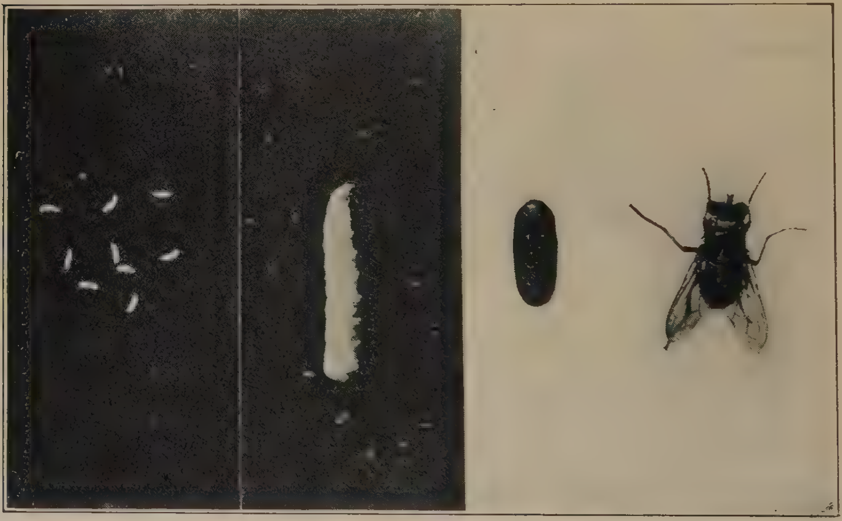

Fig. 20.—Illustrating complex metamorphosis. Life history of the common housefly. *a.* egg; *b.* larva; *c.* pupa; *d.* adult.

A greater difference is found in the young and adult grasshopper (Fig. 19). Other than the difference in size and sexual maturity the absence of wings in the young is at once apparent. In order to reach the winged condition, the young individual molts at intervals, and with each molt secures longer wings until after a definite number of molts the fully developed wings are present. The following stages may be recognized: (1) *egg,* (2) *nymph,* (3) *imago* (not sexually mature) and (4) *adult* or sexually mature individual. This type of metamorphosis is termed *simple* or *incomplete.*

The greatest difference between the newly hatched young and the parent occurs in such forms as the house fly (Fig. 20), the butterfly, etc. In these forms the newly emerged young individual has no resemblance whatever to the adult, having the appearance of a segmented worm. (Of course, the internal anatomy and certain other features are distinctly insectan.) The fact that the young are mandibulate and the adults haustellate in Diptera and Lepidoptera offers much interesting ground for ecological discussion, but is out of place at this time. In order to attain the winged condition of the adult from the wingless, wormlike condition of the young, many profound changes must be undergone and a new stage is entered, the *pupa,* or resting stage, in which this transformation is accomplished. The newly emerged young insect is called the *larva,* and we have consequently the following stages to deal with: (1) *egg,* (2) *larva,* (3) *pupa,* (4) *imago,* (5) *adult.* This type is termed *complex* or *complete* metamorphosis.

External Anatomy.—In order to familiarize himself with the external anatomy of insects, especially with the parts upon which classification is mainly based, the student should study carefully some hard-bodied insect of a generalized nature. Such an insect need not be a parasite, indeed, the author prefers that a non-parasitic form be used because there is less specialization. The common grasshopper answers the purpose very well, and a careful study of Fig. 21 is recommended.

Keys to Classification.—The student is now prepared to better understand the use of a key to classify any insect at hand. The first thing he needs to do is to place the insect in its proper order, which may be done with the aid of the following key. While the use of a key in classification of animals may seem to be essential, the student should not become a slave to this very mechanical method of placing creatures in their proper class, order or family.

KEY TO THE ORDERS OF INSECTS[1]

A. Primitive wingless insects; mouth parts well developed, but all except the apices of the mandibles and maxillæ withdrawn into a cavity in the head; tarsi (feet) always one or two clawed; body sometimes centipede-like, with well-developed abdominal legs, in this case tarsi two-clawed—(the simplest insects) . . . . . THYSANURA

AA. Normally *winged* insects, wings sometimes rudimentary or absent; mouth parts not withdrawn into a cavity in the head.

- *B. Mouth parts, when developed, with both mandibles and maxillæ fitted for biting; abdomen broadly joined to thorax; tarsi never bladder-shaped;* when mouth parts are rudimentary, if the wings are two, there are no halteres; if the wings are four or absent, the body is not *densely* clothed with scales.
  - *C. Posterior end of abdomen with a pair of prominent unjointed forceps-like appendages; fore wings, when present, short, veinless, horny or leathery*—(Earwigs) EUPLEXOPTERA

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[1] After Kellogg (by permission) arranged by Professor H. E. Summers.

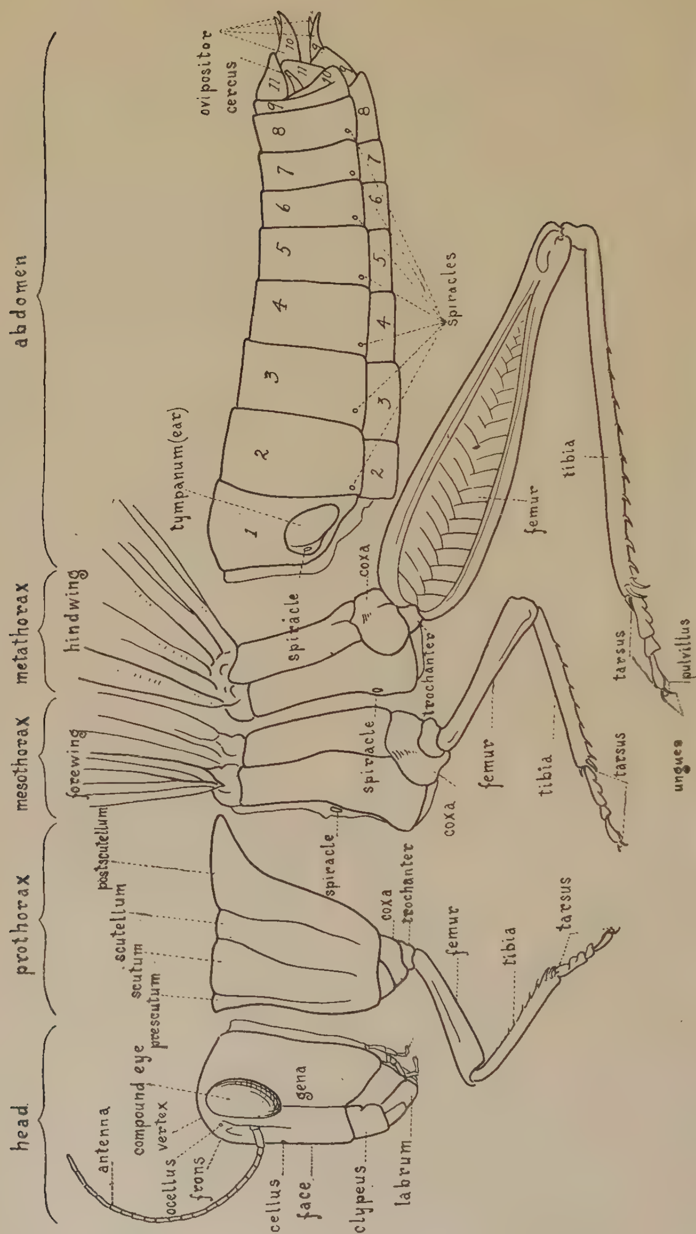

FIG. 21.—External anatomy of an insect (grasshopper), showing many of the parts commonly referred to in the classification of insects in general.

CC. Posterior end of abdomen usually without prominent unjointed forceps-like appendages; when these are present the fore wings are always developed, *veined.*

D. Fore wings, when present, veined and membranous, parchment-like or leathery, when absent, the labium (underlip) either cleft in the middle, or the mouth parts prolonged into a distinct beak.

E. Fore wings, when present, thicker than hind wings, somewhat leathery or parchment-like; hind wings folded several times, lengthwise, like a fan, in repose; when wings are absent, prothorax large—(locusts, crickets, cockroaches, etc.). ORTHOPTERA

EE. Fore wings membranous, of same structure as hind wings; hind wings usually not folded; but occasionally folded like a fan; when wings are absent, prothorax small.

F. Antennæ inconspicuous.

G. Hind wings smaller than fore or absent; posterior end of abdomen with two or three many-jointed filaments — (May flies) . . . . . . EPHEMERIDA

GG. Hind wings not smaller than fore; posterior end of abdomen without many-jointed filaments—(dragon flies and damsel flies) . . . . ODONATA

FF. Antennæ conspicuous.

G. Tarsi less than five-jointed; labium cleft in the middle.

H. Wings always present, although sometimes very small; hind wings broader than fore wings, folded in repose; prothorax large, nearly flat on dorsal surface—(Stone flies) PLECOPTERA

HH. Hind wings, when present, not broader than fore wings, not folded in repose, prothorax small, collar-like.

I. Tarsi four-jointed, wings when present equal in size—(Termites) . . . . ISOPTERA

II. Tarsi one to three jointed.

J. Tarsi one or two jointed, always wingless—(biting lice) MALLOPHAGA

JJ. Tarsi usually three-jointed; occasionally two-jointed, in which case wings always present, fore wings larger than hind wings—(Book lice, etc.) CORRODENTIA

GG. Tarsi five-jointed, but with one joint sometimes difficult to distinguish; labium usually entire in middle, sometimes slightly emarginate.

H. Wings, when present, naked or slightly hairy; hind wings with or without folded anal space; in former case prothorax large and nearly flat on dorsal surface; in wingless forms mouth prolonged into a distinct beak.

I. Mouth parts not prolonged into a distinct beak, at most slightly conical—(Dobsons, ant lions, etc.) . . . NEUROPTERA

II. Mouth parts prolonged into a distinct beak—(Scorpion flies, etc.) MECOPTERA

HH. Wings, when present, thickly covered with hairs; hind wings usually with folded anal space; prothorax small, collar-like; mouth not prolonged into a beak—(Caddis flies) TRICHOPTERA

DD. Fore wings, when present, veinless; horny or leathery; when absent, labium entire, and mouth parts not prolonged into a distinct beak—(Beetles) COLEOPTERA

BB. Mouth parts, when developed, more or less fitted for sucking; sometimes also fitted in part (the mandibles) *for biting; in this case either* (1) *base of abdomen usually strongly constricted, joined to thorax by a narrow peduncle, or* (2) *the tarsi bladder-shaped, without claws;* when mouth is rudimentary either the wings are two and halteres are present, or the wings are four or none and the body (and wings if present) are densely clothed with scales.

C. Prothorax free; body (and wings if present) never densely clothed with scales; maxillary palpi usually absent; when present, tarsi bladder-shaped, without claws.

D. Tarsi bladder-shaped, without claws; wings four (sometimes absent), narrow, fringed with long hairs; maxillæ triangular, with palpi—(Thrips) THYSANOPTERA

DD. Tarsi not bladder-shaped, usually clawed; wings not fringed with long hairs; maxilla (when mouth is developed) bristle-like, without palpi—(Bugs) HEMIPTERA (incl. Anoplura)

CC. Prothorax not free; maxillary palpi present, sometimes rudimentary and difficult to see, in which case body (and wings if present) densely clothed with scales; tarsi never bladder-shaped, usually clawed.

D. Mandibles often rudimentary, when present bristle-like.

E. Wings four (sometimes wanting), clothed with scales; body covered thickly with scales or hairs;

mouth, when developed, a slender, sucking proboscis, closely coiled under head—(Moths and butterflies) . . . . LEPIDOPTERA

EE. Wings two (or wanting), naked or with scattered hairs; hind wing in winged forms represented by halteres; body either naked or with scattering hairs; mouth, a soft or horny beak not coiled under head.

F. Prothorax poorly developed, scarcely visible from dorsal side—(Flies) . . . DIPTERA

FF. Prothorax well developed, distinctly visible from dorsal side; wings never present (Fleas) SIPHONAPTERA

DD. Mandibles well developed, fitted for biting; wings four (sometimes two or none), naked or with scattered hairs—(Ichneumon flies, gallflies, wasps, bees and ants) . . . . HYMENOPTERA

CHAPTER IV

INSECT MOUTH PARTS

Importance of Mouth Parts.—No doubt all insects possessing mouth parts capable of piercing the skin of man and beast may be regarded with some suspicion by the medical entomologist as potential vectors of certain blood inhabiting microparasites, although the blood-sucking habit may not normally prevail. The non-piercing insects manifestly cannot relate to infection introduced directly into the circulation except through previously injured surfaces. Thus, the house fly although possessing non-piercing mouth parts is recognized as an important vector of *Trypanosoma hippicum* Darling, a blood inhabiting parasite and the causative organism of murrina of horses and mules, which it carries mechanically on its proboscis contaminated while feeding from wounds caused by stable flies (Stomoxys) or other means, and conveyed thence to similar wounds on healthy animals.

The student of insects in their relation to disease must secure a thorough knowledge of the mouth parts and feeding habits of insects for at least two reasons, first that he may know how the pathogenic organisms are taken up as well as introduced and, secondly that he may know, if occasion requires, in what form insecticides should be employed if at all. The student of insect control, particularly the medical entomologist will soon find that a knowledge of the feeding habits of the adult insect alone is quite inadequate and that he must thoroughly familiarize himself with the feeding habits of the insect in all stages of its development. He will soon discover that the larvæ of many of the piercing insects have biting mouth parts, as in the mosquitoes and fleas.

Classification of Mouth Parts.—All insect mouth parts, however, highly specialized, find their origin in the simple type still practically existing in such insects as the cockroach and grasshopper. Insect mouth parts are commonly divided into two classes, namely (1) *mandibulate* (biting) as in the cockroaches, grasshoppers and beetles; and (2) *haustellate* (sucking) as in bees, butterflies and moths. This classification is far from satisfactory in the field of medical entomology as is illustrated in the following cases: the common house fly (*Musca domestica*) and the stable fly (*Stomoxys calcitrans*) both possess haustellate mouth parts (Fig. 22) and belong to the same family of insects, Muscidæ, hence are systematically closely related, yet are quite unrelated in their specific manner of disease transmission. By virtue of its efficient piercing stylets the stable fly has the power to pierce the skin and suck blood, thus becoming a direct infector while the house fly, because of the structure of its proboscis and its inability to suck blood by piercing the skin and while probably more important as a disease vector, is classed as an indirect infector or food contaminator except as before indicated.

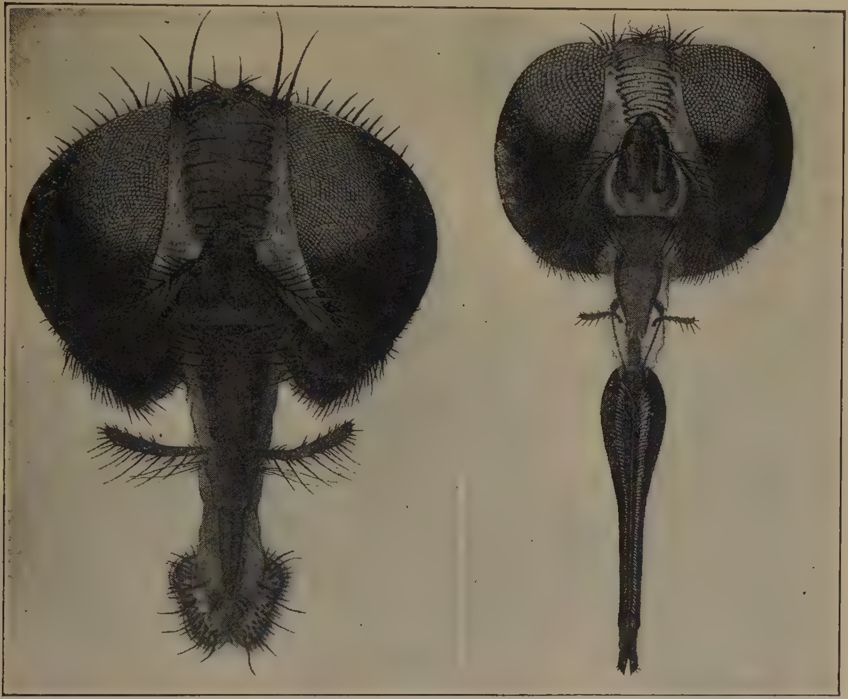

Fig. 22.—Head and proboscis of the common house fly (*Musca domestica*) on the left; the stable fly (*Stomoxys calcitrans*) on the right. Though closely related systematically, the mouth parts of the two species are very different; both are suctorial, but the former cannot pierce the skin while the proboscis of the latter encloses piercing setæ adapted for that purpose.

Obviously it would seem much more appropriate to classify insects as (1) piercing, e.g., mosquitoes, and (2) non-piercing, e.g., butterflies; which, however, leaves much to be desired, hence the following classification is suggested:

1. *Orthopteron type,*—generalized mouth parts consisting of opposable jaws used in biting and chewing; upper and lower lips easily recognized, as in the cockroach and grasshopper.
2. *Physopodan type,*—mouth parts representing a transitional type, minute in size; approaching the biting form, but functioning as suctorial organs, as in the thrips.

3. *Hemipteron type,*—mouth parts consisting of piercing suctorial organs, comprising three or four stylets closely ensheathed within the labium, forming a proboscis, as in the cone-nose and bedbug.
4. *Dipteron type,*—suctorial organs, piercing or non-piercing; no single representative is available for the entire group of Diptera, hence the following subtypes may be recognized.
   - *a.* First subtype,—mosquito; mouth parts consisting of six stylets, loosely ensheathed within the labium.
   - *b.* Second subtype,—horsefly; mouth parts consisting of six short blade-like structures used for piercing and cutting, all loosely ensheathed within the labium.
   - *c.* Third subtype,—stable fly; piercing stylets reduced to two in number, closely ensheathed within the labium.
   - *d.* Fourth subtype,—house fly; mouth parts consisting of a muscular proboscis, not suited for piercing; stylets rudimentary.
5. *Hymenopteron type,*—mouth parts consisting of suctorial, lapping organs, mandibles specialized for portage and combat, as in the bee, wasp and ant.
6. *Lepidopteron type,*—mouth parts consisting of a suctorial coiled tube, as in the butterfly.

Morphology of Mouth Parts

The Orthopteron Type.—To illustrate this type either the grasshopper or the cockroach may be used, but since the former is more easily obtainable and can be handled more satisfactorily, it will serve this purpose very well. This type, the mandibulate or biting, is the generalized or primitive form and will serve as a basis for later comparisons and derivations. It is not of direct importance in relation to medical entomology except as it furnishes a basis for a better understanding of the haustellate or sucking type.

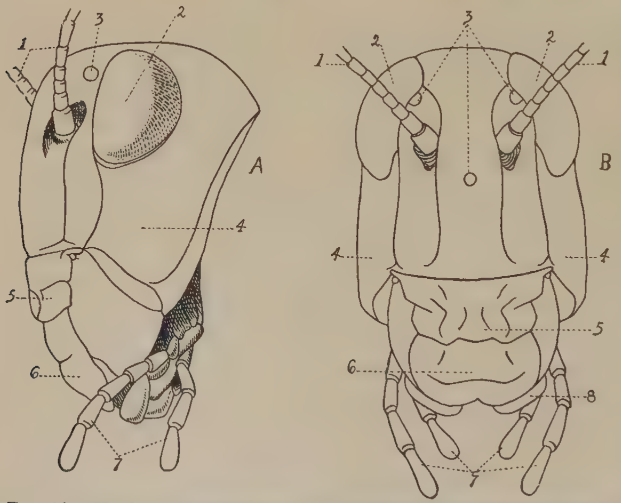

Fig. 23.—Head of a grasshopper, to illustrate the relative position of head structures in insects. A. side view; B. front view. 1. antennæ; 2. compound eye; 3. ocelli (simple eyes); 4. gena (cheek); 5. clypeus; 6. labrum; 7. palpi; 8. labium. (Redrawn after Folsom.)

If the head of the grasshopper (Fig. 23) is viewed from the side and again from the front, the relative position of the parts will be better understood. Separating the mouth parts (Fig. 24) of the grasshopper, the following structures will be observed. In front, low down on the head, hangs the labrum or upper lip, easily lifted as one would raise a hinged lid, the hinge line being at the lower edge of the sclerite or plate, known as the *clypeus*.

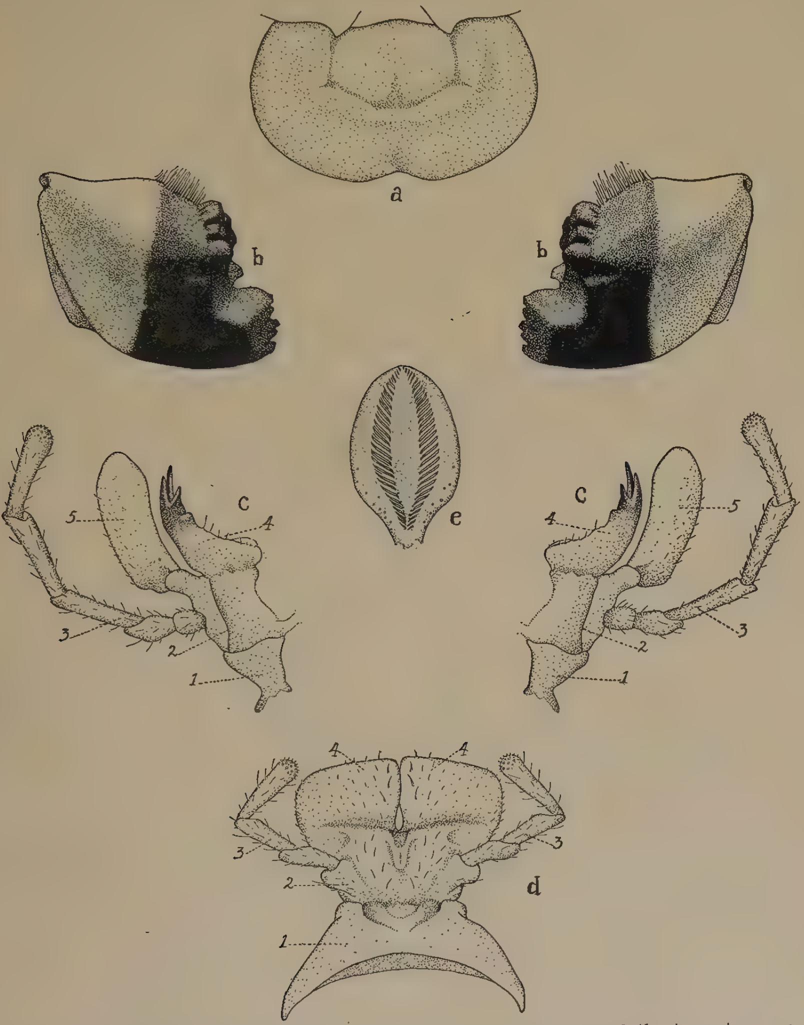

Fig. 24.—Mouth parts of a grasshopper, typical mandibulate structures, Orthopteron type. *a.* labrum; *b.* mandibles; *c.* maxilla, consisting of (1) cardo, (2) stipes, (3) palpus, (4) lacinia, (5) galea; *d.* labium, consisting of (1) submentum, (2) mentum, (3) palpus, (4) ligula; *e.* hypopharynx or tongue.

The labrum functions as does the upper lip in higher animals, i.e., it draws the food toward the mandibles. In this the labrum is greatly aided by a rough structure called the *epipharynx,* which forms the inner lining of the labrum and clypeus. Because of the close association of these two structures they are often referred to as a double organ, the *labrum-epipharynx.* Removing the labrum, a pair of heavy, black, opposable jaws, the *mandibles,* is exposed. These are biting structures *par excellence.* They are toothed and movable laterally, instead of vertically as in the vertebrates. Dislodging the mandibles brings into view the pair of maxillæ, or accessory jaws. These organs are known as *first maxillæ.* They are composite structures separable into *cardo, stipes, lacinia, galea* and *palpus,* which should be carefully observed, inasmuch as they undergo great modification in the remaining types of mouth parts. The two supporting sclerites of the maxillæ are called the *cardo* (basal) and *stipes* (the second), while the distal lobes are called (1) the maxillary *palpus* (a jointed structure), (2) the *galea* (median and fleshy), (3) the *lacinia* (inner and toothed), capable of aiding in comminuting food.

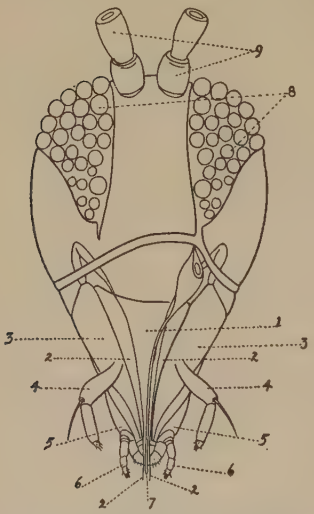

FIG. 25.—Head and mouth parts of thrips, mandibulate in structure but crudely suctorial in function. Physopodan type. Front view of head. (1) labrum, (2) mandibles, (3) maxillæ, (4) maxillary palpi, (5) labium, (6) labial palpi, (7) hypopharynx (?), (8) eyes, (9) antennæ. (Redrawn after Uzel.)

Underneath the maxillæ and forming the floor of the mouth lies the lower lip or *labium,* a double structure frequently called the *second maxilla.* On the same plan as the maxillæ, the labium consists of a basal sclerite, the *submentum,* followed by the *mentum,* upon which rest the *labial palpi* (a pair of outer jointed structures to the right and left), and the *ligula* (a pair of strap-like plates which together correspond to the upper lip). The labium is also subject to much modification in insects.

The fleshy organ still remaining in the mouth cavity after the parts just described have been removed is the tongue or *hypopharynx,* an organ of taste, functionally comparable to the tongue of vertebrates.

The mandibles are most useful landmarks, since they are almost universally present in insects, though in various degrees of development from the strong mandibles of certain beetles (Lucanidæ) to the vestigial structures in certain Lepidoptera. In the Hymenoptera, even though the order is of the haustellate type, the mandibles are nevertheless important structures, serving, for example, in the honeybee as wax implements and organs of defense, and in ants as organs of portage and combat. In Hemiptera and Diptera the mandibles are modified into piercing organs. The maxillæ are subjected to great modification.

Physopodan Type.—Though like the first type, unimportant in its relation to disease transmission, this type, the Physopodan (Fig. 25), is distinctly important phylogenetically as a connecting link between the biting and piercing-sucking mouth parts. It is in the very minute thrips (*Physopoda*) that we find a transitional type of mouth parts, biting in general structure but sucking in function. The parts are all more or less readily traceable to the generalized Orthopteron type, but have become considerably elongated for piercing and are suctorial in function.

Hemipteron Type.—A very different sort of organ than those above described is found in the Hemiptera (Fig. 26). Here the labium forms a prominent beak which is usually three (rarely one or four) jointed and telescopic. This beak incloses a pair of *mandibles,* often provided with terminal barbs, and a pair of maxillæ, all stylet-like and of great efficiency in piercing. The maxillæ are more or less completely joined, forming a tube, so that only three stylets seem to be present on examination. The *labrum* is quite short and inconspicuous.

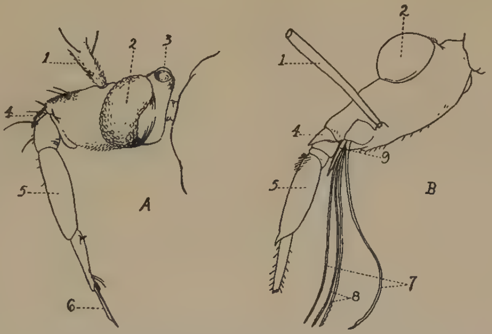

Fig. 26.—Head and mouth parts of a cone-nose, piercing and suctorial, with jointed proboscis. Hemipteron type. A. side view of head showing (1) portion of antenna, (2) compound eye, (3) ocellus, (4) clypeus, (5) jointed labium, (6) protruding setæ or piercing bristles, consisting of the mandibles and maxillæ. B. Shows setæ withdrawn from labium. (7) mandibles, (8) maxillæ, (9) hypopharynx.

Dipteron Type. — (*a*) *First Subtype, the Mosquito.*—The most generalized type of Dipteron mouth parts is found in the mosquito (Fig. 27), hence here we find the maximum number of stylets representing the structures of the more generalized type, loosely ensheathed within the elongated *labium,* the whole forming a prominent beak or proboscis. The identity of the six stylets is not well established, though it is generally accepted that they represent the two *mandibles,* the two *maxillæ* (distinctly serrated distally), the *hypopharynx,* and the *labrum-epipharynx.* The *palpi* are conspicuous structures in all mosquitoes. These represent the *maxillary palpi* of the grasshopper, while the pair of flattened lobe-like organs forming the distal portion of the proboscis are said to represent the *labial palpi* and are called the *labella.*

(*b*) *Dipteron Type, Second Subtype, the Horsefly.*—While retaining the same number of parts as the mosquito, this subtype is distinctly

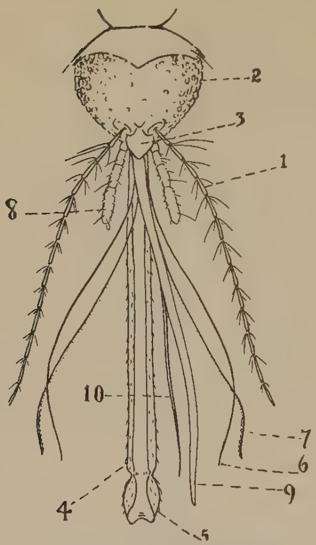

Fig. 27.—Head and mouth parts of a mosquito (*Culex sp.*). Illustrating the generalized Dipteron type of mouth parts (first subtype) with maximum number (six) of bristle-like stylets. (1) Nematoceran antennæ; (2) compound eyes; (3) clypeus; (4) labium; (5) labella; (6) mandibles; (7) maxilla; (8) maxillary palpi; (9) labrum; (10) hypopharynx.

characterized by its flattened blade-like condition (Fig. 28). That these mouth parts serve primarily as cutting structures is evident from the quantity of blood usually drawn by the "bite" of a horsefly, especially one of the larger species such as the black horsefly (*Tabanus atratus*). The *labium* is the conspicuous median portion loosely ensheathing the blades and terminating in large *labella*. The *mandibles* are distinctly flattened and saber-like, while the *maxillæ* are narrower and provided with conspicuous *palpi*. The *hypopharynx* and *labrum-epipharynx* are both lancet-like. In the male these piercing parts are very weakly developed and are not useful as weapons of attack.

(*c*) *Dipteron Type, Third Subtype, the Stable Fly*.—This subtype (Fig. 29) is represented by a group of flies in which the mouth parts are distinctly specialized for piercing, and show, together with the next subtype, to what extent these structures may become differentiated within the same family of insects.

The proboscis at rest is carried at the position of a bayonet at charge, and is therefore provided with a promi-

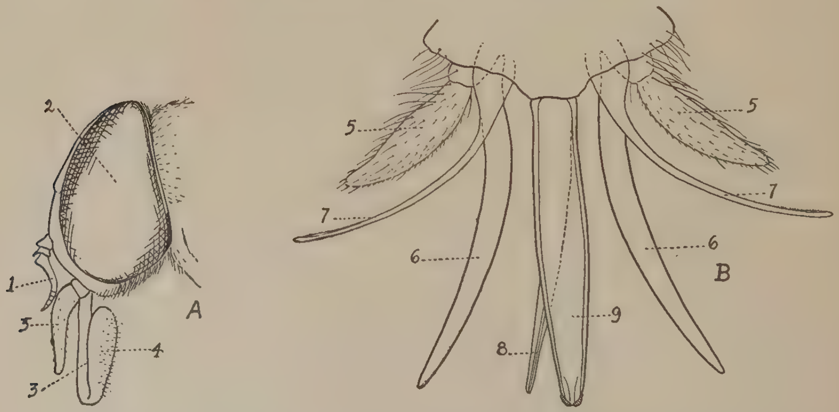

Fig. 28.—Head and mouth parts of a horsefly (*Tabanus*). The maximum number of parts is retained, but the piercing structures are distinctly blade-like. Dipteron type, second subtype. A. Side view of head showing (1) antenna (brachycerous), (2) compound eye, (3) labium, (4) labella, (5) maxillary palpus. B. Piercing structures exposed, labium removed. (6) mandibles, (7) maxillæ, (8) hypopharynx, (9) labrum-epipharynx.

nent muscular elbow or knee. This conspicuous organ (the proboscis) is the *labium* terminating in the *labella,* which are provided with a complex series of cutting and adhesive structures. Within the folds of the labium and easily removable through the upper groove lie two setæ, the *labrum,* the uppermost and heavier stylet, and the *hypopharynx,* a lower and weaker one, the two forming a sucking tube supported within the folds of the labium. The *maxillary palpi* are located at the proximal end of the proboscis.

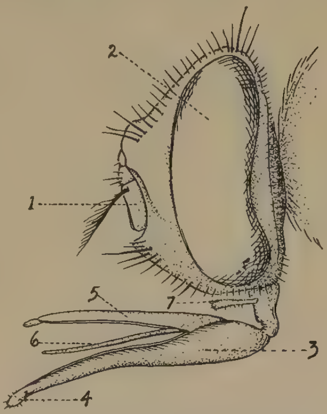

Fig. 29.—Head and mouth parts of the stable fly (*Stomoxys calcitrans*). Stylets reduced in number, closely unsheathed by the labium. Dipteron type, third subtype. Side view. (1) antenna, (2) compound eye, (3) labium, (4) labella, (5) labrum, (6) hypopharynx, (7) maxillary palpi.

(*d*) *Dipteron Type, Fourth Subtype, the House Fly.*—Here (Fig. 30) the prominent fleshy proboscis consists mainly of the labium, which terminates in a pair of corrugated rasping organs, the *labella,* and is attached in elbow-like form to the elongated head. The entire structure is highly muscular and may be either protruded in feeding or partially withdrawn while at rest. Lying on top of the grooved labium is the inconspicuous spade-like *labrum,* which forms, with the hypopharynx, a sucking tube, supported

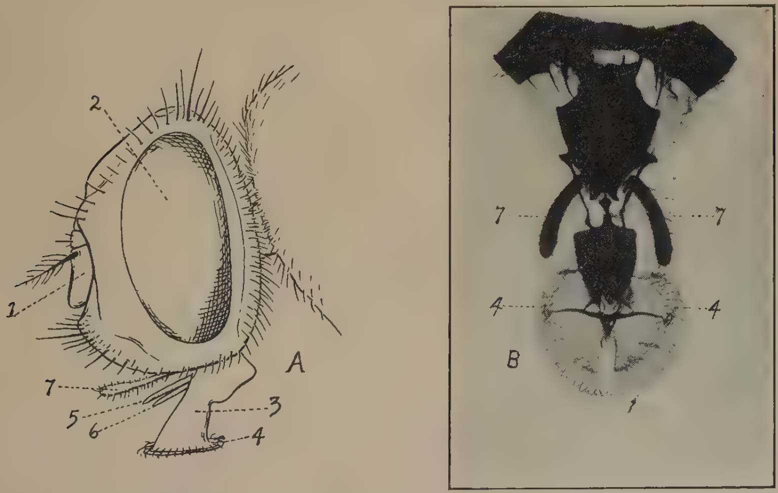

Fig. 30.—Head and mouth parts of the house fly (*Musca domestica*). Piercing stylets rudimentary. Muscular fleshy proboscis not suited for piercing the skin of higher animals. Dipteron type, fourth subtype. A. Side view. (1) Antenna, (2) compound eye, (3) labium, (4) labella, (5) labrum, (6) hypopharynx, (7) maxillary palpi; B. Front view of proboscis.

by the labium, which latter also incloses the salivary canal. By an examination of the labrum it will be seen that it forms a kind of convex covering to the concaved hypopharynx, thus giving rise to a food tube. The maxillæ have evidently become fused with the fleshy elbow of the proboscis and only the prominent *maxillary palpi* remain.

Hymenopteron Type.—In this type the two general classes of mouth structures, the *Mandibulate* and *Haustellate*, find a rather strong development in the same species, though the mandibles are not involved in the feeding process. The honeybee (Fig. 31) serves as a representative species. The *labrum* is narrow and quite simple, the *mandibles* are easily distinguishable and are useful wax implements. In ants the mandibles are highly efficient carrying organs and weapons of defense. The *maxillœ* form the lateral conspicuous wings of the suctorial parts; the *lacinia* and *galea* are fused and the *maxillary palpi*

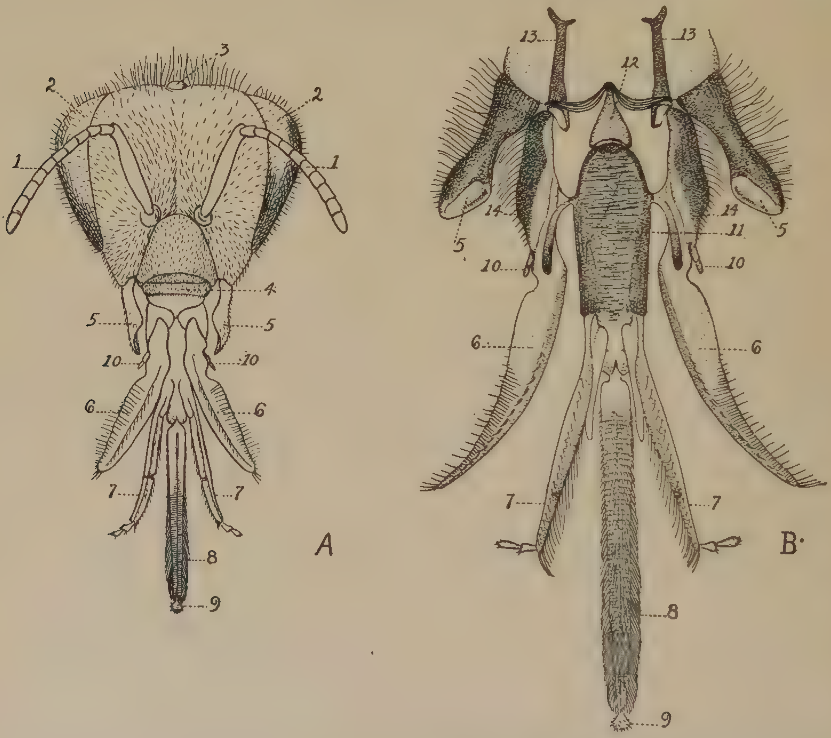

Fig. 31.—Head and mouth parts of the honeybee (*Apis mellifera*). Both types of mouth parts well developed but the mandibles are used chiefly for portage and modeling. (Hymenopteron type.) A. Front view of the head showing (1) antennæ, (2) compound eyes, (3) simple eye, (4) labrum, (5) mandibles, (6) maxillæ (lacinia), (7) labium (palpi only), (8) hypopharynx (?); B. Mouth parts removed to show the parts, (5) mandibles, (6) maxillæ (lacinia), (7) labium (palpi only), (8) hypopharynx (?), (9) bouton, (10) maxillary palpus, (11) mentum, (12) submentum, (13) cardo, (14) stipes.

are minute. The *labium* is represented by the long structures to the right and left of the middle tube which is probably the *hypopharynx.* The hypopharynx terminates in a spoon-like labellum or *bouton* which completes the lapping character of the subtype.

Lepidopteron Type.– This type, represented by the commoner butterflies and moths, is typically a coiled, sucking tube capable of great elongation. Taking the cabbage butterfly (*Pontia rapæ*) as an example (Fig, 32) the *labrum* is seen to be greatly reduced, the mandibles absent. (These may be weakly present in the lower Lepidoptera.) The maxillæ are apparently only represented by the *galeæ,* which by close approximation of their inner grooved surfaces form the long coiled proboscis. The double structure of the proboscis can be easily demonstrated by manipulation. The *labium* is represented by the *labial palpi.*

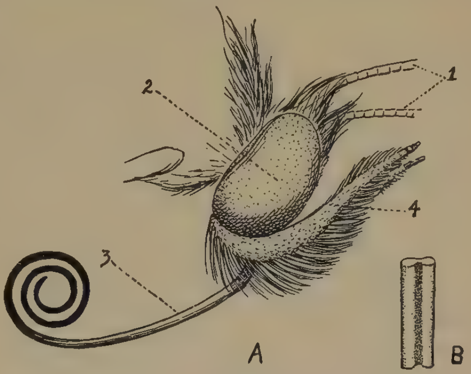

Fig. 32.—Head and mouth parts of a butterfly (*Vanessa sp.*). (*a*) Side view. Suctorial, coiled tube, Lepidopteron type. (1) antennæ, (2) compound eye, (3) proboscis, consisting only of the galeæ, (4) labial palpus. (The labrum is not visible in side view.) (*b*) Section of proboscis showing double nature.

ORDERS OF INSECTS ARRANGED ACCORDING TO MOUTH PARTS WITH TYPE OF METAMORPHOSIS INDICATED

I. *Orthopteron type.*[1] Biting or chewing mouth parts.
  1. *Order Thysanura,*—Bristletails, springtails, *et al.,* mouth parts withdrawn in cavity of head; primitive metamorphosis.
  2. *Order Ephemerida,*—May flies,—mouth parts vestigial; simple metamorphosis.
  3. *Order Odonata,*—Dragon flies and damsel flies,—simple metamorphosis.
  4. *Order Plecoptera,*—Stone flies,—simple metamorphosis.
  5. *Order Isoptera,*—White ants,—simple metamorphosis.
  6. *Order Corrodentia,*—Book lice, *et al.,*—simple metamorphosis.
  7. *Order Mallophaga,*—Biting lice,—simple metamorphosis.
  8. *Order Orthoptera,*—Grasshoppers, cockroaches, *et al.,*—simple metamorphosis.
  9. *Order Euplexoptera,*—Earwigs,—simple metamorphosis.
  10. *Order Neuroptera,*—Dobson flies, ant lions, aphis lions, *et al.,*—complex metamorphosis.

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[1] The term "Orthopteron" is here merely applied to indicate a biting type which varies considerably even in the Order Orthoptera.

11. *Order Mecoptera,*—Scorpion flies,—mouth parts prolonged into a beak with mandibles at the tip; complex metamorphosis.
12. *Order Trichoptera.*—Caddis flies (moth-like); complex metamorphosis.
13. *Order Coleoptera,*—Beetles,—complex metamorphosis.

II. *Physopodan type.* Biting in structure but sucking in function; represents a transitional form between the biting and sucking insects.

14. *Order Physopoda,*—Thrips,—simple metamorphosis.

III. *Hemipteron type.* Elongated typically 3 or 4 segmented proboscis (unsegmented in the sucking lice), snugly enclosing stylet-like organs; piercing and suctorial.

15. *Order Hemiptera,*—Cicadas, bedbugs, cone-noses, *et al.;* simple metamorphosis.
16. *Order Anoplura.*—Sucking lice; simple metamorphosis.

IV. *Dipteron type.* Unsegmented proboscis, which may or may not contain piercing stylets.

17. *Order Diptera,*—mosquitoes, flies, *et al.;* complex metamorphosis.
    - *a.* First subtype,—The mosquito,—loosely ensheathed, piercing, delicate, stylet-like structures, six in number, suctorial.
    - *b.* Second subtype,—The horsefly,—piercing, blade-like structures, six in number; suctorial.
    - *c.* Third subtype,—The stable fly,—closely ensheathed, piercing, heavy, stylet-like structures, two in number; suctorial.
    - *d.* Fourth subtype,—The house fly,—fleshy, non-piercing; suctorial.
18. *Order Siphonaptera,*—Fleas,—piercing mouth parts closely related to second subtype; complex metamorphosis.

V. *Hymenopteron type.* For feeding purposes the mouth parts are of a non-piercing, lapping type, but for purposes of combat and portage the mandibles are well developed.

19. *Order Hymenoptera,*—Ants, bees, wasps, *et al.;* complex metamorphosis.

VI. *Lepidopteron type.* Proboscis in the form of a greatly elongated coiled tube; non-piercing, suctorial.

20. *Order Lepidoptera,*—Moths and butterflies; complex metamorphosis.

CHAPTER V

HOW INSECTS CAUSE AND CARRY DISEASE

Ecological Factors Must be Determined.—In the investigation of insect-borne diseases a knowledge of pathogenic microörganisms (bacteria, protozoa, helminths and fungi), is highly desirable, if not absolutely essential, not only to inspire confidence and security on the part of the experimenter, but also on the part of those whom he serves. In order to know where the insect takes up the disease producing agent and how it becomes infective, the habits of pathogenic organisms must be studied, their habitat in the body of the diseased host must be sought, the gateways of escape must be ascertained, their longevity and virulence when away from the host and many other ecological factors must be determined. After having picked up the pathogenic organism its course within the body of the insect must be studied in order to know how it makes its escape therefrom and reaches the body of the next host. A knowledge of insect habits is essential.

To illustrate, bubonic plague is a bacillary disease caused by *Bacillus pestis* of which the rat is an important host and man readily succumbs to the same. While these organisms may pass from host to host in several ways, it has been found that fleas are the most important vectors. The bacilli are found in greatest abundance in the buboes which are situated largely in the axillary and inguinal regions of the rat, and it has been found that these regions are favored by fleas, which, due to their blood sucking habits, imbibe the highly infective fluids. If the rat dies of the plague, the fleas leave the cold body and seek another host, which interval in the change of hosts raises the question of resistance and longevity of the bacilli. Can the bacilli resist the digestive fluids of the flea and if so how long can they live in the flea in an infective condition, and in the meantime what course have these organisms taken within the body of the insect and how will they make their escape? Then follows a chain of interesting inquiries. How will the flea find another host and what animals will it attack? How long can the flea live without food? How are the plague bacilli introduced into the body of the next victim? Will the flea remain infective throughout the rest of its life?

Malaria is caused by a protozoön animalcule (*Plasmodium*) which lives under far more restricted conditions than does the plague bacillus. In the human being it is blood inhabiting and so far as is known does not occur in other warm blooded animals and has as its sole definitive host certain mosquitoes belonging to the genus Anopheles. Although many other blood sucking insects imbibe parasitized blood these do not offer the necessary environment for the completion of the life cycle of the parasite. No doubt the reason for the intimate relation between the Anopheline mosquito and the plasmodium is to be found in the realms of biological chemistry.

Insects as Direct Cause.—The economic entomologist in the course of his day's work deals with many kinds of insects and has many questions to answer concerning their relation to human affairs, of which none is less important than the inquiry, Is it dangerous? Numerous classifications could be established to designate direct pathological relationships and among those used by various authors are the following: (1) *accidental injury* to sense organs caused by insects coming in contact with or gaining access to ears, eyes and nose and which may result in more or less serious irritations; (2) *dermatosis* caused by burrowing chigoes, itch mites, etc.; (3) *myiasis* caused by the attack of fly larvæ such as Texas screw worms and the bot flies; (4) *blood loss* due to blood sucking insects is probably not an important factor in itself but no doubt all such insects inject certain quantities of salivary fluids into the "bites," causing a more or less local or systemic reaction or poisoning, such as flea bites, spider bites, etc.

Insect Venoms.—Pathological conditions traceable to insect venoms might appropriately be placed under the previous heading as already indicated, but since such venoms are of considerable importance in the study of medical entomology special attention should be called to the subject. Venoms of insects although little understood produce definite reactions and may be introduced into the body in one of three ways: (1) by *contact,* e.g., irritating hairs of certain caterpillars, such as the brown tail moth (*Euproctis chrysorrhœa* Linn.), or vesicating fluids of the blister beetles such as *Lytta vesicatoria* Linn.; (2) by the *bite* or pierce of such insects as the cone-noses (Reduviidæ) and certain spiders; (3) by the *sting* of bees, wasps and scorpions. (See Chapter on Venomous Insects and Arachnids.)

How Insects Carry Disease.—The large number of diseases carried by arthropods as suggested in the historical introduction to our study, and in consequence the great variety of pathogenic organisms involved, each with its own peculiar behavior, together with the many species of vectors, also representing a great variety of habits, is indicative of the fact that there are many different ways in which insects and arachnids and related animals (Arthropoda) carry disease. The simplest way appears to be through the agency of food contamination. Any insect might accidentally come in contact with infective excrement or sputum and in turn accidentally come in contact with food to be eaten by humans or other animals. In this connection the normal breeding and feeding habits of the insects are determining factors. Thus under this classification *coprophagous* insects are particularly important. Many species of flies and beetles breed in excrement and these together with roaches, ants and other insects often visit such wastes when available as a source of food. Not only do pathogenic bacteria and protozoa, when present such as those of typhoid fever and entamœbic dysentery, cling to the mouth parts, feet, wings and other parts of the insect body but they may also be swallowed and pass uninjured through the alimentary canal and be deposited with the insect's feces, such as fly "specks," on food or be regurgitated with the same result. The eggs of certain species of worms, notably pin worms (*Enterobius vermicularis*), may be similarly spread. Furthermore, it has been amply proved that fly larvæ, which develop in excrementous matter, may pass on bacteria through every stage of the insect's development to the adult. Thus may also the germ of anthrax (*Bacillus anthracis*) be passed on in the case of flesh fly larvæ breeding in the bodies of animals killed by this disease. The spread of the organisms is not accomplished until the winged insect appears. This is a strong argument in favor of the incineration of the bodies of dead animals.

A second purely mechanical method of disease transmission is by means of a *contaminated piercing proboscis,* in which the mouth parts in feeding become contaminated with blood inhabiting pathogenic organisms. This method is of course restricted to insects with piercing mouth parts, although it has been shown in a previous paragraph that the house fly, with its non-piercing proboscis, may accidentally fall into this category. Insects which fall into this class of carriers usually have strong, piercing mouth parts capable of drawing considerable blood and are intermittent feeders, going readily and quickly from one animal to another, such as the Stomoxys flies, horseflies (Tabanids) and tsetse flies.

A somewhat different type of insect portage occurs in the transmission of bubonic plague by fleas. Here the carrier is also provided with piercing mouth parts, is blood-sucking and intermittent in its feeding habits. The plague bacilli (*Bacillus pestis*) are taken either into the stomach passing through the alimentary canal without attenuation, being deposited on the skin of the person or animal bitten with the flea's feces and subsequently "rubbed in" by the person or animal in scratching or rubbing the wound, or the bacilli may become lodged in the esophagus of the flea and then regurgitated into the lesion produced by the bite.

The greatest complexity is found when the insect carrier becomes a *necessary intermediary host of the pathogenic microörganism,* e.g., the Anopheline mosquito in its relation to the malaria plasmodium. Here a given period of time must elapse after the insect imbibes infective blood before it can become an infective carrier. This period corresponds in this case to the time required for the plasmodium to pass through its sexual cycle in the stomach of the mosquito and find its way into the salivary glands of the same, ready to be inoculated into the blood of the person bitten by the insect.

CHAPTER VI

COCKROACHES—BEETLES

A. The Cockroaches

Order Orthoptera, Family Blattidæ

Few insects invading the household are looked upon with as much disgust as are the cockroaches. Fortunately the night prowlings of these insects and their secretive habits by day may spare the otherwise good reputations of many restaurants and hotels. The sanitary inspector, particularly the food inspector, who suggests the presence of these loathsome creatures without much strong evidence, is due to have a good argument on his hands. Evidence in material form is not always essential, for be it known to all inspectors the odor of cockroaches is difficult to conceal.

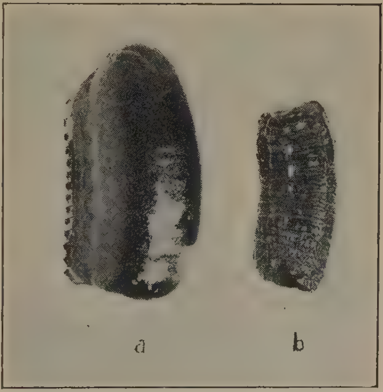

FIG. 33.—Egg cases (oöthecæ) of cockroaches. (*a*) oriental roach; (*b*) croton bug. × 5.

General Characteristics.—Cockroaches belong to the family Blattidæ of the order Orthoptera and are extremely active runners. Although there are numerous species (nearly a thousand being described) very few have become habitually house invaders in temperate climates. Roaches have characteristically dorsoventrally flattened, smooth bodies and are chestnut brown to black in color. The head is rather decidedly inflexed under the body and the many segmented antennæ are extremely long and slender. There are two pairs of wings when present. The wings of the males are usually well developed while those of the females are short or vestigial in several species. The outer pair of wings is thick and leathery, while the inner is membranous and folded. While the fully winged forms possess the power of flight, the group as a whole is running in habit and can cover ground in this manner with remarkable rapidity.

The mouth parts are of the generalized orthopteron (biting) type and provided with strong mandibles. Their food habits may be classed as almost omnivorous, with a special preference for starchy and sugary materials. They attack human foods in practically all stages of preparation and apparently feed on anything that lies in their path from the most delicate viands to the vilest excretions, even feeding upon their own cast off skins and their dead and crippled kin. They feed at night, being typically nocturnal in habit. Where during the daytime everything may appear to be free from these pests, one may hear the crackling of their bodies under foot at night when abundant, if one should chance to invade their haunts after dark.

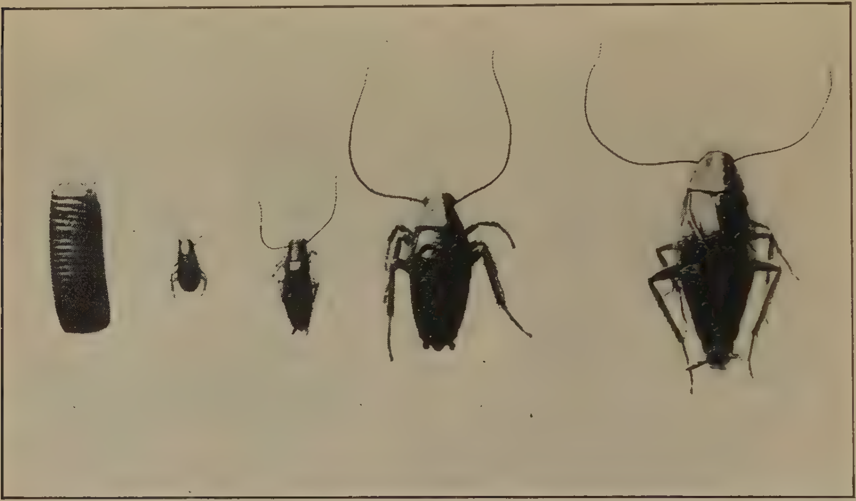

Fig. 34.—The croton bug (cockroach), *Blatella* (*Ectobia*) *germanica*, in various stages of development. The adult female is shown with egg case or oötheca in normal position protruding from the terminal abdominal segment. × 2.

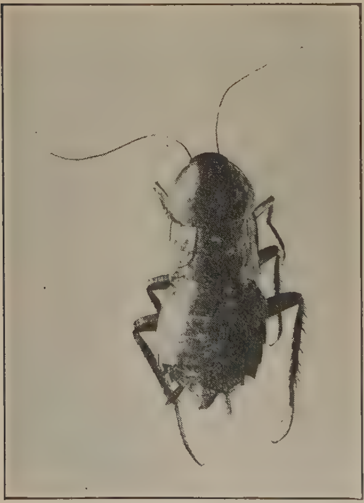

Fig. 35.—The oriental roach, *Blatta orientalis*. × 1.3.

Not only do roaches disgorge portions of their meal at intervals after feeding and drop their feces on unprotected surfaces, but they also discharge a secretion both from the mouth and from scent glands which imparts a disagreeable and nauseous odor to anything with which it comes in contact, particularly food and dishes, and is very difficult to eradicate.

Life History.—The eggs of the roach are assembled in the body of the female in a chitinous capsule or *oötheca* (Fig. 33) which when completed is often carried by the insect for several weeks partly protruding from the abdomen. The individual eggs are arranged in a double row within the capsule, and in the croton bug there are usually thirteen pairs. When the young are ready to hatch the oötheca is deposited usually in some dark corner or crevice and the female apparently keeps her brood close together for a short while. The young on hatching are almost white and very soft, but soon become brownish and hard and resemble the adults except for size and absence of wings. Their development is evidently quite slow as our observations go to show. The young roaches molt soon after hatching and again in about four weeks and four or five times thereafter reaching full growth usually within a year. There appears to be but one generation a year, though no doubt temperature and food conditions have much to do with their rate of development. Roaches can apparently live a long time without food or water; Holt reports in the London *Lancet* (June 3, 1916) that one individual had survived for 76 days in a petri dish.

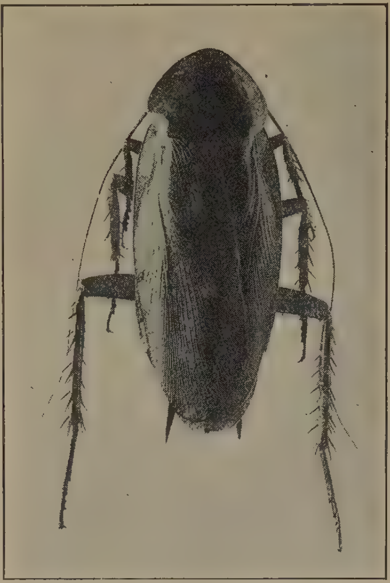
FIG. 36.—The American cockroach. *Periplaneta americana.* × 1.3.

Species and Distribution.—As household pests cockroaches are widely distributed, brought about chiefly through maritime trading; holds of vessels as well as the crew's sleeping quarters are oftentimes overrun with these miserable pests. The most widely distributed species are the croton bug, *Blatella germanica* Linn. (Fig. 34), and the oriental roach, *Blatta orientalis* Linn. (Fig. 35). The former is one of the smallest species, measuring about five-eighths of an inch to the tip of the wings, which are present in both sexes. This species is evidently the most common form along the north Atlantic and north Pacific coasts, as shown by observations made in Boston, New York and San Francisco. The name croton bug has been applied to this insect because of its appearance during the construction of the Croton water system of New York City. In color the insect is a muddy brown with two longitudinal stripes on the pronotum.

The oriental roach is an inch or more in length and is very much darker than the croton bug, hence is often called "black beetle" (the term beetle being wrongly applied). The female has vestigial wings, while in the male these organs are short, reaching not quite to the tip of the abdomen. This form is common in the eastern and central states and the author has taken it in various localities in California.

Another house-infesting species is the native American cockroach, *Periplaneta americana* Linn. (Fig. 36), a light chestnut-colored species, which reaches a length of an inch and a half and has long wings in both sexes. This is also a common species in the middle and western states, being especially abundant in Mexico and Central America. It resembles a slightly shorter species occupying about the same territory in the United States, namely, *Periplaneta australasiæ* Fabr. (Fig. 37), which differs further in that the Australian roach has a yellowish border around the pronotum, extending partly down the outer margins of the wing covers. One of our commonest native outdoor species is *Ischnoptera pennsylvanica* De G. To these common forms might be added a list of exotic roaches constantly coming to our shores on shipboard from the Orient and elsewhere, but which have never secured a foothold.

Roaches as Carriers of Infection.—Roaches as already suggested invade situations where infective excrement and sputum may occur and are actually known to feed on such. That they feed on human food in practically all stages of preparation is a matter of common observation. Hence their habits certainly afford ample opportunity for the contamination of food. Two questions can be easily answered by two simple experiments, namely, "Can the roach pick up specific bacteria?" In answer to this a croton bug was allowed to crawl over a culture of *Bacillus pyocyaneus aureus,* a green chromogen, in a test tube. The growth on the agar in this tube was not profuse. The insect was next transferred to a sterile agar plate upon which it was permitted to walk one minute. The roach was then liberated and transferred to a second plate for one minute, and then to a third plate in a similar manner. The agar plates were then incubated for 24 hours at a temperature of 37° C. At the end of this time a good growth of the green chromogen, *Bacillus pyocyaneus aureus,* had developed on all three plates. Secondly, Can the roach carry specific bacteria to human food? Having determined in the preceding experiment that the roach can pick up known organisms, we next exposed one grain of sugar to a roach which had previously walked across an agar plate culture of *Bacillus pyocyaneus aureus,* the same chromogen used before. The insect remained with the sugar, feeding on it for three minutes. The sugar was then dissolved in 5 cc. of sterile water and plated on three agar plates, using 1 cc. of the solution for each. The plates were incubated for 24 hours at 37° C. *Bacillus pyocyaneus aureus* was recovered on all three plates, the growth on none being scanty. This simple experiment can easily be repeated by students who wish to prove in the laboratory that certain insects may become food contaminators.

Longfellow[1] has shown that *Bacillus coli communis, B. proteus vulgaris, Staphylococcus aureus, S. citreus,* and a bacillus of the subtilis type are carried on the legs of roaches and that the same organisms are found in the feces, passing uninjured through the alimentary tract. However, the most important results have been obtained by Barber[2] experimenting with the roach *Periplaneta americana* Linn. He fed cholera dejections to roaches and found that a single insect would frequently ingest as much as 0.2 cc. In eight cases cholera vibrios were recovered from the insect's feces and in one case as long as 79 hours after feeding. After the vibrios were discharged by the roach on such moist materials as fresh beef, lettuce, etc., they remained mobile for at least 16 hours and no less of virulence was observed when the vibrios remained in the insect's intestine as long as 29 hours. Barber also found that the roaches disgorge portions of their meal at intervals after feeding and that such disgorged material contained cholera vibrios.

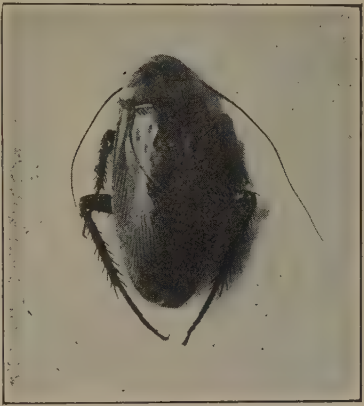

Fig. 37.—The Australian roach *Periplaneta australasiæ.* × 1.2.

The Bacterial Population of the Croton Bug.—Six individuals were selected from a collection of roaches taken from various localities and permitted to crawl for one minute over six sterile agar plates (one roach for each plate). These plates were incubated for 48 hours at 37° C. Each plate showed a good growth, the colonies on examination proving to be saprophytic without exception.

To secure an approximate estimate of the number and kind of bacteria carried by roaches, two of these insects were treated as follows. After sterilizing pipettes, forceps, tubes, etc., 5 cc. of distilled water was placed in each of the five test tubes. Into these tubes were placed the legs and antennæ of the roaches,—the posterior pair of legs of one roach into one tube, those of the other roach in a second tube, the antennæ of both roaches in a third, and the remaining pairs of legs of the first roach in the fourth and the remaining pair of legs of the other roach in the fifth tube. The stomach contents were plated on agar. The tubes were shaken vigorously for three minutes in order to wash the parts well and then 1 cc. of the water in each tube was plated on agar and incubated 24 hours at 37° C. The results were all positive, as the following table (Table I) indicates:

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[1] Longfellow, R. C., 1913. The common house roach as a carrier of disease. Amer. Journ. of Public Health, Vol. III, No. 1, pp. 58-61.

[2] Barber, M. A., 1914. Cockroaches and ants as carriers of the vibrios of Asiatic cholera. Philippine Journ. of Sci., Sec. B, Vol. IX, No. 1, pp. 1-4.

TABLE I

Showing Number and Kind of Bacteria Carried on Individuals of the Croton Bug

No. of the Roach	Part of the Roach Plated	Bacterial Count per cc.	Kind of Bacilli Present
1	Posterior pair of legs	1200^+	(*a*) *Staphylococcus albus* (*b*) Non-spore-bearing bacillus
2	Posterior pair of legs	1600^+	(*a*) *Staphylococcus albus* (*b*) Non-spore-bearing bacillus
1	Remaining legs	950	(*a*) *Staphylococcus albus* (*b*) Small non-spore-bearing bacillus (*c*) Spore-bearing air bacillus
2	Remaining legs	1200	(*a*) Spore-bearing air bacillus (*b*) *Staphylococcus albus*
1–2	Antennæ	384	(*a*) Spore-bearing air bacillus (*b*) *Staphylococcus aureus* Yellow pigment
1	Stomach contents	14	(*a*) Minute bacilli (unidentified)
	Total	5348^+	for a dilution of ⅕

$5 \times 5348^+ \div 2 = 13{,}370^+$ bacteria, — minimum number present on each roach

From the above table it will be seen that each roach carried on its feet and antennæ and in its stomach a minimum of 13,370 bacteria. While this does not represent a fair estimate for all roaches, since only two individuals were used, we are here shown that the roach can carry a large number of bacteria. Esten and Mason (Storrs Agric. Exp. Sta., Bull. No. 51) have shown that the number of bacteria carried by a fly range all the way from 550 to 6,600,000, with an average of one and one fourth million bacteria on each. Thus by comparison it may be seen that the roach probably carries fewer bacteria.

It is furthermore interesting to note that there were more bacteria on the single pair of posterior legs than on the remaining two pairs combined. This is probably explained by the use the cockroach makes of its hinder pair of legs. The tibiæ and tarsi are in contact with the surface on which the insect walks, being parallel with the body. Very often the insect stands on the hind pair of legs, with the remaining legs barely touching the surface. The fore legs are also frequently brushed by the antennæ.

The Roach an Intermediary Host of Nematodes.—It was very early known that cockroaches may become infected with *Filaria rytipleurites* Deslgch. of the rat by feeding on rat feces, and that other rats may become infected in turn by feeding on roaches. Galeb, in Comprend Rendu (1878), reports that he discovered numerous parasites in the adipose tissue of the roach *Blatta orientalis,* which were found to be identical to nematodes found in the rat, *Epimys decumanus.* He also found hair of the rat in the alimentary canal of the roach. On feeding rats (*Epimys rattus*) with infected roaches and examining them after the expiration of eight days, he found the parasites in the folds of the mucous membrane of the stomach. Several nematodes (three females and one male) had already developed sexual organs. According to Fibiger, reporting to the *Berliner Klinische Wochenschrift* in February, 1913 (pp. 289-298), much evidence is produced that certain nematode parasites (Spiroptera) of the rat produce true malignant tumors. Eggs of these nematodes were found in the rat feces but no embryos and he reports that none developed for six months and also that rats could not be infected with the eggs, the roach being a necessary intermediary host. Two species of roaches were used, namely, *Blatta orientalis* and *Periplaneta americana.* Ransom and Hall[1] found that although Aphodius beetles are the normal carriers, the croton bug (*Blatella germanica*) might also serve as an intermediary host for *Gongylonema scutatum* (Müller) a nematode parasite of sheep and cattle.

Control.—Numerous methods have been evolved to combat the cockroach, and it is quite certain that this insect can be controlled in dwellings, restaurants and similar situations. One method which has been found useful for the larger less abundant forms is a trap. This consists of a deep, smooth-walled vessel (fruit jar or the like) into which is placed a favorite roach food, such as chocolate or molasses (stale beer or ale are also recommended). Sticks leading to the top of the jar must be provided in order that the roaches can easily reach the mouth, and in their endeavor to get at the food tumble into the trap. If there is a liquid in the trap, the roaches are drowned, otherwise they must be killed by scalding, burning, oiling or otherwise.

Trapping methods are least successful in the control of the croton bug; it is certainly far more wary than the larger species. The ordinary glass-jar-trap method employed for the larger species is not effective. The croton bug can crawl up the sides of a glass jar without difficulty and thus make its escape. A dark box trap is preferable with one or more tubular pasteboard entrances projecting both inside and outside. The mouth of the tube inside the box must be guarded either with a single trap door or adhesive substance around the outside of the tube and immediately adjacent to the mouth to prevent the roaches from escaping after feeding on the bait. The box may be baited with sugar, sweet chocolate, a little stale beer or the like. After the roaches have been captured they are shaken out through a lid into kerosene or hot water. The box is then once more baited and placed in position.

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[1] Ransom, B. H., and Hall, M. C., 1915. The life history of *Gongylonema scutatum.* Journ. of Parasitology, Vol. II, No. 2, pp. 80-86.

More satisfactory results are obtained by means of poisons. When the word *poison* is used in this connection it does not necessarily imply that it is a poison also to human beings, since there are some materials which act in this way when eaten by insects but are non-poisonous to human beings, except, of course, when taken in large quantities; among such materials are borax and sodium fluorid. Borax is frequently used as an ingredient in the preparation of roach and ant poisons. Thus equal parts of chocolate, or powdered sugar, and borax well mixed (this is important) provide an excellent roach powder. This powder should be placed in little heaps or in windows easily accessible, or may be sprinkled in the crevices whence the insects come.

Dusting with Sodium Fluorid is by all odds the most effective means of ridding a place of roaches. Marlatt[1] says commercial sodium fluorid, either pure or diluted one half with some inert substance such as powdered gypsum or flour may be dusted or blown over shelves, tables, floors and the runways and hiding places of roaches.

> "The immediate effect is to cause these insects to come out of their retreats and rush about more or less blindly, showing evidence of discomfort, to be eventually followed in the course of a few hours by their death. Those dead or paralyzed roaches can be swept up and burned and complete extermination is effected within 24 hours. It is not definitely known whether the sodium fluorid acts as a contact insecticide through the breathing pores or as a stomach poison. Probably, however, it acts in both ways as it has been found to kill caterpillars fed on foliage dusted with this substance."

The continued and repeated use of such repellents as eucalyptus oil, oil of citronella, oil of rosemary, and naphthaline may be of service where other methods are undesirable for some good reason. Also the use of a poison bait is recommended by Pettit in the Journal of Economic Entomology for April, 1920 (p. 260) against *Periplaneta americana,* viz., a thin gruel of cotton seed meal sweetened with a little molasses and cooked, to which is added, when cool, a cake of yeast and when fermented a little powdered lead arsenate. The moist bait is placed in the haunts of the roaches.

Two methods mentioned by Felt[2] are the following: "The smoke of burning gunpowder is very obnoxious and deadly to roaches, particularly the English roach. The moistened powder should be molded into cones, placed in an empty fireplace and ignited. It is particularly valuable in the case of old houses." A second method, viz.: "A relatively simple method, described by Mr. Tepper of Australia, is to mix plaster of Paris, one part, and flour three or four parts, in a saucer and place the preparation about the haunts of the pests. Near by there should be a saucer containing a little water and made easily accessible to the roaches, laying a few sticks as bridges up to the rim. The insects eat the mixture, drink the water and soon succumb."

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[1] Marlatt, C. L., 1915. Cockroaches. U. S. Dept. of Agric. Farmers' Bulletin 658, 15 pp.

[2] Felt, Ephraim Porter, 1909. Control of Household Insects. New York State Museum, Bulletin No. 129 (Albany).

Fumigation with hydrocyanic acid gas, carbon bisulphid or sulphur may be resorted to with much success; however, this should not be undertaken without experience, since the behavior of these gases must be fully understood.

B. The Beetles

Order Coleoptera

The beetles may easily be distinguished from other insects by the following characters: the mouth parts are of the biting type, mandibles strongly developed; two pairs of wings are present of which the forward pair is hardened and does not overlap at the tip; the ventral portion of the abdominal segments consists of chitinous plates extending at least halfway round the body. (In other insects these ventral plates are much shorter as a rule.)

The metamorphosis of Coleoptera is complex (egg, larva, pupa, imago) with the occurrence of hypermetamorphosis in a number of species. The larvæ of this order are commonly called "grubs" and may be recognized by the presence of three pairs of rather feeble legs.

Scavenger Beetles.—All the scavenger beetles are of interest in this connection since the habit of feeding on dead animal matter might accidentally bring them in contact with infection. Infection may be carried in two ways, namely, first mechanically on the body, legs or mouth parts, or secondly, in the excreta. The latter method involves attenuation in that the pathogenic organism may become reduced in virulence in its passage through the alimentary canal of the insect.

Among the families of scavenger beetles are the Staphylinidæ or rove beetles (not all animal feeding), recognized by the abbreviated condition of the wing covers (elytra), thus exposing the abdomen dorsally, and giving these beetles a larval or worm-like appearance, augmented by the flexibility of these parts. The functional wings are folded up and concealed under the elytra. The range in size in this family is enormous. One very small species in the act of swarming is known to get into the eyes of people when driving, cycling or motoring, causing a severe burning sensation by means of the vile-smelling body secretions. The species commonly met with on turning over carcasses, hides, heaps of bones and other animal rubbish, belong to two genera; namely, Creophilus (Fig. 38 left) and Staphylinus (Fig. 38 right), which include species ranging from one half to one inch in length. A second family to be considered are the Silphidæ, or sexton beetles, also known as carrion beetles. In habit these insects are more decidedly scavenger than the preceding, feeding almost exclusively on dead flesh, both as larvæ and adults. Again two genera will serve to illustrate the commoner forms, namely, Silpha (Fig. 39 left) and Necrophorus (Fig. 39 right). These two genera are well illustrated as to relative size and general shape by the accompanying figures.

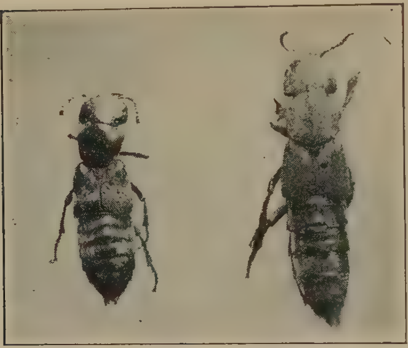

Fig. 38.—Rove beetles (Staphylinidæ). *a.* Creophilus; *b.* Staphylinus. × 1.5.

A third family, the Histeridæ, is composed of a group of small-sized, short, shining, black beetles commonly found about decomposing animal matter.

The fourth family, Dermestidæ, also includes only small forms, about one third of an inch and less in length. In shape they are elliptical, usually dark grayish or brownish in color. Skins and other animal specimens in museums are often ruined by the museum pest, *Anthrenus museorum* Linn. or *Anthrenus verbasci* Linn., if proper precautions are not taken. This damage is practically all done by the larvæ, as is the case with the larder beetle, *Dermestes lardarius* Linn. and *D. vulpinus* Fabr. and the carpet beetle, *Anthrenus scrophulariæ* Linn.

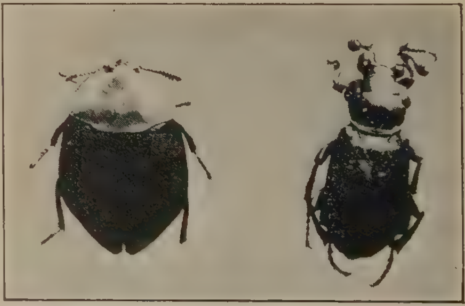

Fig. 39.—Sexton beetles (Silphidæ). *a. Silpha americana; b. Necrophorus sp.* × 1.5.

Relation to Disease.—Where hides taken from anthracic animals or the carcasses are attacked by scavenger insects it is more than likely that there will be danger from this source. The following statements taken from Nuttall[1] bear directly on this subject, viz.:

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[1] Nuttall, George H. F. On the Rôle of Insects, Arachnids and Myriapods, as carriers in the Spread of Bacterial and Parasitic Diseases of Man and Animals. Johns Hopkins Hospital Reports, Vol. VIII, Nos. 1-2, 1899.

"Proust (1894), in examining goatskins taken from anthracic animals, found quantities of living *Dermestes vulpinus* upon them. He found virulent anthrax bacilli in their excrements, as also in the eggs and in the larvæ. It is evident from this that these insects which feed on the skins permit the anthrax spores to pass uninjured through their alimentary tract. Heim (1894) also had occasion to examine some skins which were suspected of having caused anthrax in three persons engaged in handling the leather. He found larvæ of *Attagenus pellio* Linn., *Anthrenus museorum* Linn. (both Dermestidæ) and Ptinus, also fully developed insects of the latter species on the skins. All these insects had virulent anthrax bacilli (spores) on their surface and in their excreta, from which Heim concludes they might spread disease. He says the excreta are very light and easily scattered by the slightest current of air. Heim does not believe the bacilli multiply in the bodies of these insects, but that the latter may be dangerous through their scattering the spores about."

May Beetles and Thorn-headed Worms.—May beetles or cockchafers (Family Scarabæidæ) are known to be intermediary hosts both in the larval and adult stages of the thorn-headed worm (Fig. 40), *Gigantorhynchus gigas* (Goeze), a parasite of swine also said to occur in man in rare cases. This nematode worm in its adult stage measures from 20 to 30 cm. in length and about 3 to 5 mm. in thickness, and inhabits the small intestine of its host. The eggs are deposited in this habitat and pass out with the feces which may be swallowed by the larvæ of the cockchafers. These are often extremely abundant among the rootlets of grass in heavily sodded pastures, and swine with free range are exceedingly fond of these grubs, in search of which they diligently root up the soil with their snouts. Thus every opportunity is given for the grubs to become infected and in turn the swine.

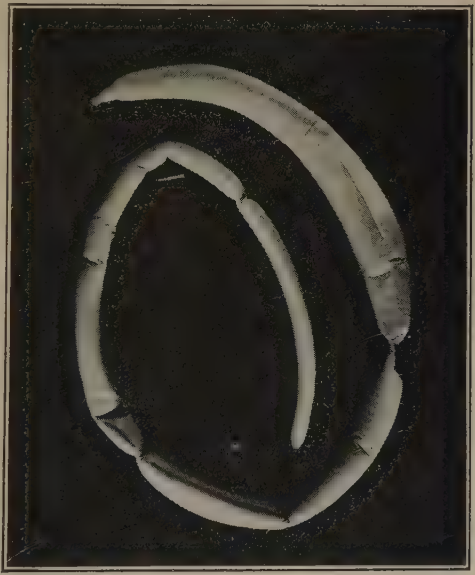

FIG. 40.—Thorn-headed worm, *Gigantorhynchus gigas*, of swine, requiring a May beetle (Lachnosterna or Melolontha) as intermediary host. × 1.

After the ova have been ingested the larvæ hatch in a few days within the intestine of the insect and proceed to burrow through the intestinal wall and into the muscles, where they are said to encyst themselves. In Europe the intermediary host is commonly *Melolontha melolontha* Linn. (*vulgaris* Fab.) and *Cetonia aurata* Linn. May beetles of the genus Lachnosterna (Fig. 41) (according to Stiles, *Lachnosterna arcuata* Smith and others) are probably all more or less concerned. The life history of nearly all May beetles is quite long, the larval stage alone often requiring nearly three years.

In districts infested with the thorn-headed worm a systematic crusade against cockchafers would be the logical means of control, together with the treatment of swine with vermifuges, the swine being properly coralled so that the feces can be disinfected.

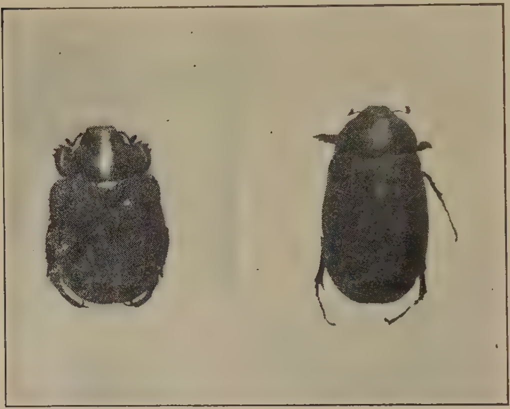

Fig. 41.—May beetles or cockchafers, *Cotalpa lanigera* (left) and *Lachnosterna fusca* (right). Serve as intermediary hosts for the thorn-headed worm of swine. × 1.2.

Rose Chafers Poisonous to Poultry.—The rose chafer, *Macrodactylus subspinosus* Fab. (Fam. Scarabæidæ) has been found to be poisonous to chickens, ducklings, goslings and young turkeys by Lamson.[1] He found that chickens fed in quantity on rose chafers showed the following symptoms after from four to five hours:

> "Drowsy appearance, with wings drooping, the eyes closed, and a slight shaking of the body. This drowsiness increased, leg weakness developed, until the chickens no longer stood, but slept resting on their feet and legs, and later died. Death occurred usually from five to twenty-four hours after they had fed upon the rose chafers. Convulsions occurred in about five per cent of the deaths. Chickens that survived the twenty-four-hour period after eating rose chafers seldom died from the poison, though they did not seem altogether normal for several days afterward."

Saw-toothed Grain Beetle.—At least one case has been reported to the writer in which the saw-toothed grain beetle, *Silvanus surinamensis* (Linn.) (Fig. 42), of the family Cucujidæ, invaded sleeping quarters, causing great annoyance to the occupants by nibbling at and crawling about on the body. The infestation, which lasted several days, was traced to the bathroom, thence out of the house through the yard and into an old barn under the stalls, where unquestionably grain from the manger had accumulated and where these beetles had been bred in great numbers. The dry California summer had pretty surely driven these insects to the bathroom for water, and the attack upon the occupants of the adjoining bedchamber was merely an incidental matter.

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[1] Lamson, G. H., Jr., 1922. The Rose Chafer as a cause of death of chickens. Storrs Agric. Exp. Sta. Bull. 110, pp. 117-134.

However, it is interesting to note that an instance is recorded in Braun's *Parasites of Man*, viz., "Taschenberg records this beetle as having invaded some sleeping apartments adjoining a brewery where stores were kept, and annoying the sleepers at night by nipping them in their beds."

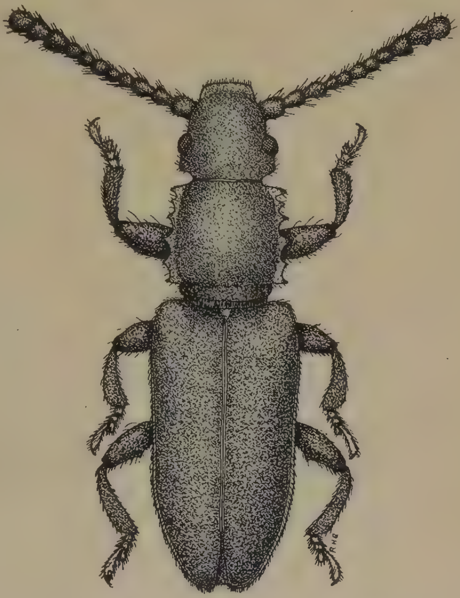

Fig. 42.—The saw-toothed grain beetle, *Silvanus surinamensis*. × 33.

Cantharidin, Spanish Fly.—Although a few other insects secrete vesicating fluids, the principal source for medicinal purposes is the group of insects known as the blister beetles (Meloidæ) of which the Spanish fly, *Lytta vesicatoria* Linn. (Fig. 43), is the most important member. This beetle is a European form found most abundantly during a certain season of the year in Spain, southern France and even at times in Germany; Petrograd supplies also a large quantity of superior cantharidin. The Spanish fly possesses a fine golden green or bluish color, ranges from ½ to ¾ of an inch in length and makes its appearance quite suddenly in early summer, when it may be collected by the hundreds, clinging principally to such vegetation as the ash, privet and lilac. The peculiar hypermetamorphosis of these insects and their larval habits give to them some obscurity during their early development and the sudden appearance and equally sudden disappearance, owing to short adult life, lent the belief that they were migrating forms.

The collection and preparation of the beetles provides an occupation for many persons during the brief period. This process also requires special precautions owing to the vesicating properties of the insects. The best quality of cantharidin produced from the pulverized beetles is the result of special care in the drying, which must be gradual. Of cantharidin, Sollman[1] (p. 705) says it is the most important local irritant.

> "It is a crystalline principle, the anhydrid of cantharidic acid. It combines readily with alkalines, forming soluble salts . . . it was isolated by

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[1] Sollman, Torald, 1908. Textbook of Pharmacology, 1070 pp. W. B. Saunders Co.

Robiquet in 1812 from the Spanish fly . . . *Lytta vesicatoria*. . . . Cantharidin is readily absorbed from all surfaces. Even when applied to the skin, sufficient may be absorbed to irritate the kidneys, so that fly blisters are contraindicated in nephritis. It is excreted mainly by the kidneys. It irritates the gastro-intestinal tract even when injected hypodermically so that some must be excreted by this channel. . . . Cantharidin penetrates the epidermis quite readily and produces violent but superficial irritation. This results in vesication. Very small quantities suffice for this purpose, ⅒ mg. cantharidin . . . will produce blisters on the human skin in the course of a few hours."

As to *therapeutic uses* the same author states:

"Cantharis is the most useful of vesicants. . . . The vesicant action of cantharides develops rather slowly. (It) is one of the most useful remedies in the treatment of baldness. It is used in the form of tincture, very greatly diluted with alcohol. For treatment of impotence Cantharis is one of the most certain, acting through reflex irritation from the urethral mucous membrane. *It is, however, quite dangerous, since effective doses are apt to set up considerable nephritis.*"

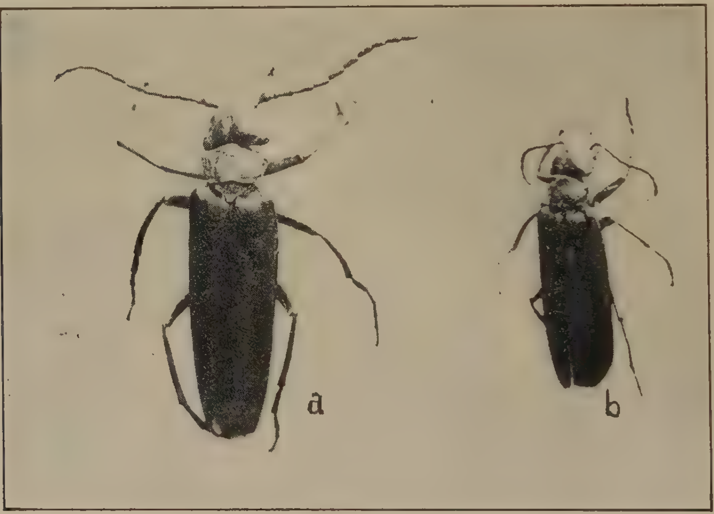

FIG. 43.—The Spanish fly, *Lytta vesicatoria*. *a*. female; *b*. male. × 2.1.

Beetles in Early Materia Medica.—Historically, a most interesting phase of our subject is a study of insects as they have been employed in early days in the treatment of diseases. Beetles have contributed a most notable list of remedies as the following extract from Kunze's Entomological Materia Medica (1893) given here for its historical interest only will indicate:

"*Coccinella septem-punctata*, or Lady-bird, was formerly considered a very efficacious remedy for colic and measles. It has also been recommended for toothache, and it is handed down that if one or two such beetles are mashed and put in the cavity of the tooth, to immediately relieve the pain. In the family of Gold-beetles, or *Chrysomelidæ,* of which there are many brilliantly colored species, there is one deserving of notice. The Colorado Potato Beetle, or *Doryphora decemlineata,* furnishes a pest to farmers and poison to human beings. Delicate persons engaged in picking these bugs from plants are frequently poisoned by the crushed insect, the juice of which inoculates when coming in contact with abrasions or by being absorbed. Volatilization of the juice, when the insects are killed in boiling water and the fumes are inhaled, produces the same effect. Victims of such poisoning after death presented a condition of defibrinated blood.

"Leather-beetles, or *Dermestidæ,* which are so destructive to skins and hides not deprived of hair, have not been used by modern civilization as a medicine. Several species of *Dermestes* were held in high esteem by the Egyptians. No less than three species were found embalmed in mummies when they were examined at Thebes. The *Dermestes typographus* was referred to by Galen, and he claimed that it is not unlike cantharis in its action; and the same opinion was held by Dioskorides. In Arabic this beetle is called *Dud chabath elsanawbar,* and Elscherif says, if reduced to a powder and applied in substance, the flesh will rot if long enough exposed to its action. On this account it is used for opening furuncles and abscesses.

"The mandibles of the Stag-beetle, *Lucanus cervus,* of Europe, were employed as medicine under the name of 'horns of scarabæi.' This remedy was given as an absorbent in cases of pains or convulsions supposed to have been produced by acidity of the *primæ viæ.* Schroeder records that the *Scarabæus cornutus,* which some suppose to be identical with *Lucanus cervus,* has been recommended to be worn as an amulet for an ague or pains, and contractions of the tendons if applied to affected parts. And if tied to the necks of children it enables them to retain their urine. The oil prepared of these insects by infusion is recommended by the same author in pains of the ears if dropped into them. It is supposed that Pliny refers to the same insect when he says: 'Folke used to hang beetles about the neck of young babes as present remedies against many maladies.'

"The Dung-beetle, or *Scarabæus* proper, was used medicinally. Pliny says that the green scarabæus has the property of rendering the sight more piercing of those who gaze upon it, and that hence engravers of precious stones use these insects to steady their sight. Schroeder says that the powder of *Scarabæus pilurarius* 'sprinkled upon a protuberating eye or a prolapsed anus, is said to afford singular relief'; also that 'an oil prepared of these insects by boiling in oil till they are consumed and applied to the blind hæmorrhoids by means of a piece of cotton, is said to mitigate the pains thereof.' And Fabricius, the entomologist, states that the *Scarabæus copris* is medicinally employed in China. Mouffet, in his *Theatrum Insectorum,* states: 'The Beetle engraven on an emerald yields a present remedy against all witchcraft, and no less effectual than that ruby which Hermes once gave Ulysses. . . . It keeps away likewise the headache, which truly is no small mischief, especially to great drinkers.' Speaking of the *scarabæus,* Pliny says: 'And many there be, who by the directions of magicians, carried about them in like manner, i.e., tied up in a linen cloth with a red string, and attached to the body, for the quartan ague, one of these flies or beetles that use to roll up little balls of earth.' Galenus says that oil in which *Scarabæi* have been roasted is good for earache, deafness and hæmorrhoidal swellings. Also against the bite of scorpions. The juice of *Scarabæus,* if applied to the eye in minute quantity, according to Elscherif and others, is good for weakness and loss of sight.

"Of the Skipjack-beetle, or *Bupestris,* Pliny says: 'Incorporate with goat-sewer, it taketh the tettars called *lichenes* that be in the face.' Dr. James records that insects of this family (*Buprestidæ*), 'are all in common inseptic, exulcerating, and possess a heating quality; for which reason they are mixed up with medicines adapted to the cure of Carcinoma, Lepra and the malignant Lichen.'

"Glow-worms, or *Lampyridæ,* come in for a share of medical lore. Of the *Noctiluca Terrestris,* Dr. James says that the whole insect is used in medicine and recommended against the stone. And Cardan ascribed anodyne properties to it. The ignorant of Italy have a notion that the phosphorescent light of fireflies or glow-worms proceeds from graves, and partakes of a spiritual form. Hence they are very careful to avoid these beetles.

"Church-yard Beetles, or *Blapsidæ,* so much dreaded in Sweden when one of these black insects enters a house, are much used in the Levant to make people plump. *Blaps sulcata,* of Egypt, is eaten for this purpose by the women of the Nile country. In Egypt and the Levant, it is used as a remedy for pains and troubles of the ears, and against the bite of the scorpion. The *Blatta,* mentioned by Pliny, from his description is evidently *Blaps mortisaga,* or Church-yard Beetle, instead of the insect now known by that name, the cockroach of our own time. This beetle is also prepared with oil and applied as a remedy for troubles of the ear. It was employed, too, externally for all kinds of dermoid affections.

"The Weevils, or *Curculionidæ,* furnish a grub or larva of white color, some of the tropical species of which grow to the size of a little finger and inhabit the pith of palm-trees. One species, *Calandra palmarum* or Palm-weevil, is a black beetle, and its larva, called *Grougrou,* lives in the trunk of the cabbage-palm. This grub furnishes an epicurean morsel in the Brazils and West Indies, where it is roasted and fried. Antonio de Ulloa says that this grub has the singular property of producing milk in women. Professor Gergi published in Florence the history of an insect he called *Curculio entiodontaligicus,* of which the larva or grub furnishes the remedy. A number of these grubs are crushed between the fingers until digits have absorbed sufficient oil therefrom. Then if an aching tooth be touched with the anointed finger, the pain will be removed. He wrote this wonderful account in the latter part of the eighteenth century. Other kind of *curculios,* he relates, have been used by the Tuscan peasants as a charm for toothache.

"The Musk-beetles, or *Cerambidæ,* furnish another drug of entomological origin. Drury, the great entomologist, records that the common *Cerambyx moschatus,* when dried, reduced to powder and applied as a vesicatory in the manner of the officinal cantharides, produces a similar effect, and in as short a time."

CHAPTER VII

THE LICE

A. The Biting Lice

Order Mallophaga

General Characteristics.—The members of the two orders of lice, Anoplura and Mallophaga, resemble each other in many particulars but differ radically in their feeding habits, the former being bloodsuckers while the latter are feeders on scales and other products of the skin which are chewed by the insects. Wings are absent in both groups, the legs are in part adapted to clinging to hairs and feathers, and the bodies are distinctly compressed. The Anoplura, or sucking lice, have a protrusible proboscis at the tip of the head; the Mallophaga, or biting lice, have a pair of distinct mandibles situated on the under side of the head. The biting lice are, as a rule, much more active than the sucking lice.

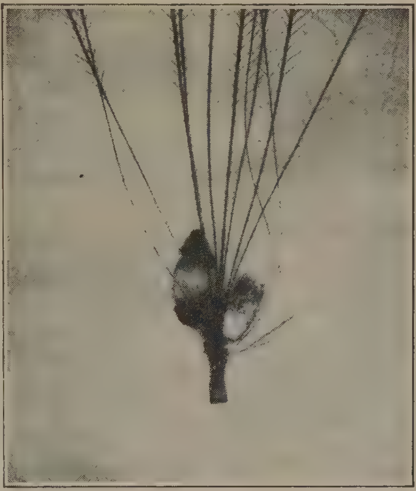

Fig. 44.—Eggs of biting lice (Mallophaga) on feathers of a bird. (Much enlarged.)

The Anoplura are inhabitants of mammals while the Mallophaga inhabit both mammals and birds and in all cases are permanent ectoparasites limited to a specific host, very rarely except accidentally transferring to a different species. The entire life cycle is normally spent on one host.

The common name "bird lice," often applied to the Mallophaga, is misleading as above suggested, hence the term "biting lice" should be substituted.

Life History.—The breeding habits and life history of the members of the two orders of lice are quite similar; however, these will be discussed in greater detail later in this chapter. The eggs are attached to the hairs or feathers of the host (Fig. 44), near the base in each case, being glued fast by means of a cement secreted by the female louse. This fluid secretion flows around the base of the egg and the hair, featherlet, or fiber and quickly hardens to form a firm attachment. The eggs or "nits" are deposited singly over a period of two or three weeks, apparently corresponding to the length of life of the adult insect. The total number of eggs has not been worked out accurately for any one species of biting louse, though Lamson[1] gives thirty-five to fifty as the number for the "short-nosed" cattle louse (Anoplura) and Nuttall states from 275 to 300 for the body louse of humans (also Anoplura). Although there is considerable difference in the incubation period of lice in general, this does not vary much beyond 5 to 8 days for the biting species. The young lice resemble the adults except for size and molt four or five times before reaching maturity in from 3 to 4 weeks.

Injury Done by Biting Lice.—The injury done by the biting lice is largely restricted to poultry, although some trouble may result when mammals are badly infested. The injury is largely due to irritation or itching caused by the creeping insects and their incessant gnawing at the skin and covering. This irritation causes the host to become exceedingly restless, thereby affecting its feeding habits and proper digestion resulting in unthriftiness. Egg production in fowls is greatly reduced and development retarded. A lousy flock of poultry is not a good investment. When lice are abundant there is usually found to be uncleanliness and overcrowded conditions.

Classification.—The biting lice (Mallophaga) of which there were about 1,400 species[2] in 1916 may be divided into two suborders with 1,257 species according to Kellogg[3] in 1908: (1) Amblycera with short, clavate or capitate, four segmented antennæ, concealed in shallow cavities or under side of head; four segmented palpi, mandibles horizontal; and (2) Ischnocera, with short, slender three or five segmented, exposed antennæ, no palpi, mandibles vertical.

Kellogg divides the Amblycera into two families, viz.: (1) Gyropidæ,—tarsi with one claw, infesting mammals only, e.g., *Gyropus ovalis* Nitzsch and *Gliricola porcelli* (Shank), both of the guinea-pig; and (2) Liotheidæ,—tarsi with two claws, infesting birds mainly, e.g., *Menopon pallidum* Nitzsch, the "shaft louse" of chickens, and *Trinoton luridum* Nitzsch of ducks. He also divides the Ischnocera into two families, viz.: (1) Trichodectidæ,—antennæ three segmented, tarsi with one claw, infesting mammals only, e.g., *Trichodectes scalaris* Nitzsch of cattle, and (2) Philopteridæ,—antennæ five segmented, tarsi with two claws, infesting birds mainly, e.g., *Goniodes stylifer* Nitzsch the large turkey louse, and *Lipeurus variabilis* Nitzsch, the "wing louse" of chickens.

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[1] Lamson, G. H., Jr., 1918. Cattle Lice and Their Control. Bulletin No. 97, Storrs Agric. Exp. Sta., Storrs, Conn., pp. 397-414.

[2] Harrison, Launcelot, 1916. The Genera and Species of Mallophaga. Parasitology (Cambridge), Vol. IX, No. 1, pp. 1-156.

[3] Kellogg, V. L., 1908. Mallophaga, in Wytsman's *Genera Insectorum.*

Lice Infesting Domestic Fowls.—More than forty species of lice are said to occur on domestic fowls of which seven species are commonly found on chickens. Losses due to poultry lice are most evident among the young birds, but heavy infestations on older fowls result in loss of weight, lowered egg production and lowered vitality. Although other maladies may present similar symptoms, infested fowls are droopy, lower the wings, present an unkempt and ruffled appearance and suffer from diarrhea. The commoner lice of chickens are: (1) the "body louse" (*Menopon biseriatum* Piaget) is a rapidly running species occurring on all parts of the fowl but mainly on the body where it crawls around on the skin; it is light yellow in color and about 2 mm. in length (Fig. 45); it lays its eggs in large clusters particularly on the small feathers below the vent; the egg stage requires about a week and maturity is reached in about two weeks thereafter; (2) the "shaft louse" (*Menopon pallidum* Nitzsch) which resembles the body louse very closely but is smaller in size and occurs mainly on the shafts of the feathers; it is said to gain its nourishment from barbs and scales of the feathers and is therefore not as irritating as the former species;

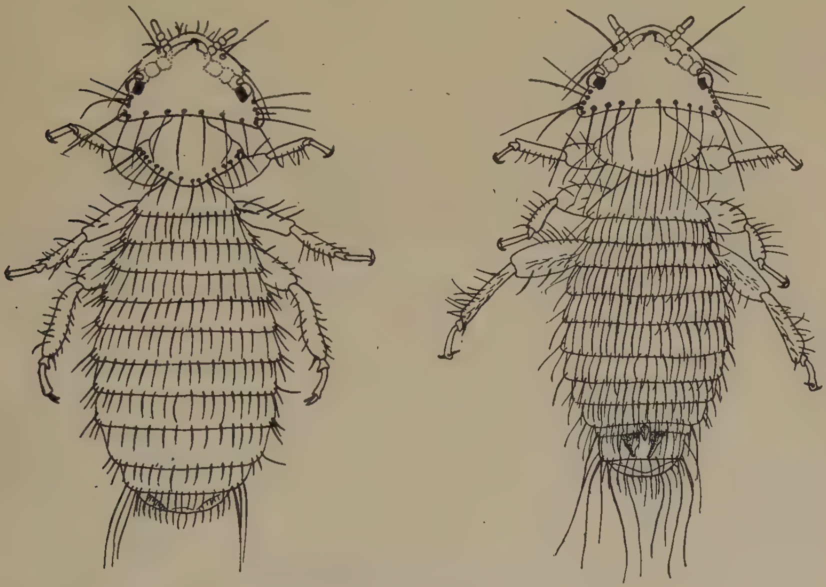

Fig. 45.—A common hen louse, *Menopon biseriatum.* Male, left; female, right. × 33.

according to Bishopp and Wood[1] it does not occur on young chickens and deposits its eggs singly, at the base of the feathers between the main shaft and the after shaft; the life history appears to require a somewhat longer time than the former species; (3) the "head louse" (*Lipeurus heterographus* Nitzsch) is a dark grayish species about 2 mm. in length, infesting the head and neck of young chickens on which it is most injurious; it deposits its eggs singly on the down or small feathers about the head and requires about the same time for complete development as the first species mentioned; (4) the large hen louse or "blue bug" (*Goniocotes abdominalis* Piaget) (Fig. 46) is about 3 mm. in length, broad with rounded head and smoky gray in color; it is generally distributed over the body and easily recognized; (5) the "wing louse" (*Lipeurus caponis* Linn. = *Lipeurus variabilis* Nitzsch), also known as the "variable louse" is a long slender species about 2 mm. in length; the margins of the head are black, the head is large, rounded and the general appearance is sufficiently distinct to separate it from all the other species; (6) the "fluff louse" (*Goniocotes hologaster* Nitzsch) is a very small and broad species about 1 mm. in length, pale in color and seldom abundant; (7) the "brown louse" (*Goniodes dissimilis* Nitzsch) is reported for the southern United States by Bishopp and Wood; it is described by them as somewhat smaller than the large hen louse and reddish-brown in color and found on the feathers of the body.

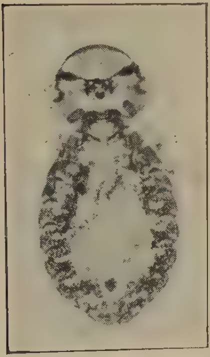
Fig. 46.—The large hen louse, *Goniocotes abdominalis*. × 10.

Turkeys are commonly infested with the large (3 mm. long) *Goniodes stylifer* Nitzsch (Fig. 47) which has the posterior angles of the head extended backward into long projections terminating in stylets or bristles. Another louse found on turkeys is *Lipeurus polytrapezius* Nitzsch, a long slender species measuring from 3 to 3.5 mm. in length. *Ducks* and *geese* harbor a rather small-sized species, *Docophorus icterodes* Nitzsch, measuring about 1 mm. in length in which the head is curiously expanded and rounded in front and has a darkish red head and thorax with darker bands; another species infesting ducks and geese is *Lipeurus*

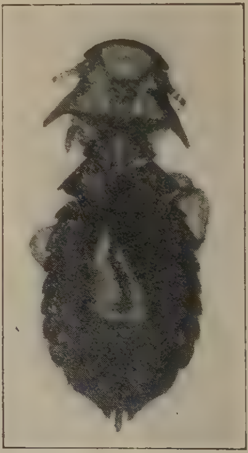
Fig. 47.—A turkey louse, *Goniodes stylifer*. × 14.

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[1] Bishopp, F. C., and Wood, H. P., 1917. Mites and lice of poultry. U. S. Dept. of Agric., Farmers' Bull. 801, 27 pp.

squalidus Nitzsch (Fig. 48) which is about 4 mm. in length, head longer than broad, very slender and light yellowish in color. Another long species infesting ducks (4 mm.) is *Trinoton luridum* Nitzsch, dark grayish in color with triangular head about as long as broad. None of these species appears to become abundant enough to be of any great consequence. The common lice of the swan are *Docophorus cygni* Denny, about 1 mm. in length; "in color the head, thorax and legs are bright reddish brown while the abdomen is white in the center and dark brown at the sides, the brown occupying hard plate-like portions at the side of each segment"; and the extremely large and common *Ornithobius bucephalus* Piaget (4 mm. long). The latter is conspicuous because of its size; the body is white and quite transparent.

Pigeons are often abundantly infested with *Lipeurus baculus* Nitzsch, a very slender species measuring about 2 mm. in length; *Goniodes damicornis* Nitzsch, a broad brownish species about 2 mm. long, and *Goniocotes compar* Nitzsch, about 1 mm. in length, whitish in color with a rounded head in front. *Guinea fowls* are said to harbor *Goniodes numidianus* Denny, *Lipeurus numidæ* Denny and *Menopon numidæ* Gieb.; pea fowls, *Goniocotes rectangulatus* Nitzsch, *Goniodes falcicornis* Nitzsch and *Menopon phæstomum* Nitzsch; pheasants, *Goniocotes chrysocephalus* Gieb., *Goniodes colchicus* Denny, *Lipeurus heterographus* Nitzsch and *Menopon fulvo-maculatum* Denny.

Control of Poultry Lice.—No remedy has given such uniformly satisfactory results in the control of the lice of all kinds of domesticated birds than has sodium fluorid (NaF.), apparently first used against these parasites by Bishopp and Wood in 1917. This remedy has been very carefully tested with excellent results in the great poultry centers of California. Sodium fluorid can be obtained in two forms, a white powder or commercial form (90 to 98 per cent pure) and in fine crystals or chemically pure. For louse control the former more finely powdered form is preferable. It retains its efficiency almost indefinitely if kept in a dry place in stoppered bottles or cans. One application generally will destroy all lice present. It may be applied in three ways, viz., the pinch method, dusting and dipping.

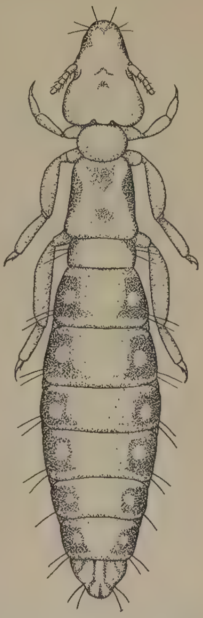
FIG. 48.—A duck louse, *Lipeurus squalidus*. (Redrawn after Osborn.) × 19.

The *pinch method* consists of placing on the skin of each fowl approximately ten "pinches" (amount held between thumb and forefinger) of the commercial sodium fluorid distributed on the breast, each thigh, below the vent, on each side of the back, on the neck, on the head, and finally one sprinkled on the underside of each outspread wing. The birds, when treated, should be held over a shallow pan or newspaper in order that the excess of the chemical may be saved.

Dusting.—The powdered sodium fluorid is sometimes mixed with three or four times its bulk of flour or talc and applied with a large shaker, ruffling the feathers of the bird as the chemical is applied. This procedure is not as economical of material or as efficient as the pinch method and the excess of chemical in the air is irritating to birds and operators.

Dipping in sodium fluorid solution is rapidly becoming a standard method of treatment among a large group of producers that have overcome the poultrymen's prejudice against wetting their birds. In California, birds may be dipped safely in almost every month of the year by choosing a warm day with little wind and completing the operations an hour or two before sundown in order that the fowls may dry thoroughly before roosting for the night. The solution should be prepared in a wooden container, avoiding contact with galvanized iron. The ordinary wooden wash tub is excellent for this purpose. One ounce of the commercial sodium fluorid or two thirds of an ounce of the chemically pure crystals should be dissolved in each gallon of tepid water. The best method for dipping the birds is to hold them with the left hand by both wings. They are then placed feet foremost in the warm dip and submerged until only the head remains above the surface. They should be held in this position from 20 to 25 seconds while the feathers are being ruffled to permit penetration of the liquid. Just before removal the head should be ducked under the surface. The birds should be held above the dip for 2 or 3 seconds to allow them to drip before releasing them. One hundred birds will use up approximately five gallons of dip, on which basis material should be available at the start of operations to keep the dip replenished.

The dipping method kills all lice immediately, but where it is applied as a powder three or four days pass before elimination is complete. If the birds are caught and handed to the operator from 100 to 125 birds an hour can be treated by dipping or dusting and approximately 60 to 75 per hour by the "pinch" method.

Other Methods.—The very fact that poultry wallow in dust whenever available indicates a means of partly controlling the bird lice. Special box wallows, conveniently placed, broad and deep enough so that there will be room for several birds at a time, should be partly filled with fine road dust or ashes with the addition of a quantity of tobacco dust in the proportion of about six parts of the former to one of the latter. It is quite desirable to add a few handfuls of sulphur. The finer the dust the better, since it is believed by some that the dust particles enter and clog up the breathing pores of the lice. However, it is more probable that the agitation caused by the birds wallowing in the dust dislodges many of the lice and they are thus lost in the shuffle. A very good louse powder for dusting birds by hand is prepared by mixing gasoline, 3 parts, and carbolic acid (about 90 per cent pure), 1 part, and stirring into this mixture enough plaster of Paris to take up the moisture. When preparing this mixture, it must be borne in mind that the gasoline is highly inflammable and that the carbolic acid is poisonous and injurious to the skin. Pyrethrum powder or buhach (fresh) applied to the hen directly by means of a duster is also a good remedy, as is dusting with flowers of sulphur. Naphthaline flakes in the nests and naphthaline nest eggs while fairly effective, are injurious both to the hens and the eggs. Dipping chickens in a 2 per cent solution of chlorin is recommended by some. After a flock of birds has been freed from lice all new acquisitions should be treated before being placed with them.

We have found powdered derris root applied as a dust or as a dip, one-fourth ounce to a gallon of water, to be effective. This method is also described by Wells, Bishopp and Laake.[1]

Biting Lice of Domesticated Mammals.—The biting lice of the domesticated mammals are for the most part rather easily identified by their presence on a given host, as commonly not more than one species of Mallophaga is found on each species of mammalian host. *Cattle* are often heavily infested on the withers, root of tail, neck and shoulders with *Trichodectes scalaris* Nitzsch (Fig. 49), a little reddish-yellow louse about 1½ mm. in length, definitely marked with transverse bars (ladder-like) on the abdominal segments. The white eggs are deposited on the hairs of the host and the entire life history from egg to egg requires about three weeks. The lice are most numerous on the animals during dry, cold weather when the hair is long. Although the biting lice do not irritate the cattle as much as sucking lice, the following noteworthy observation is made by Imes:[2]

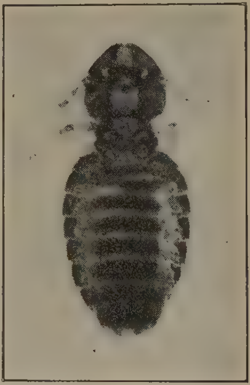

FIG. 49.—The biting ox louse, *Trichodectes scalaris*. × 26.

> "When present in large numbers, however, they often form colonies or groups around the base of the tail, over the withers, and on other parts of the animal, and produce lesions resembling those of scab. These lesions vary in size from that of a 25-cent piece to 4 or 5 inches in diameter. The skin over these areas appears to be raised and ringworm may be suspected, but when the lesion is manipulated the scarf skin falls off, exposing the lice grouped on the raw tissues beneath. Under such conditions the irrita-

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[1] Wells, R. W., Bishopp, F. C., and Laake, E. W., 1922. Derris as a promising insecticide. Journ. Econ. Ento., Vol. 15, No. 1, pp. 90-95.

[2] Imes, Marion, 1918. Cattle lice and how to eradicate them. U. S. Dept. of Agric., Farmers' Bull. 909, 27 pp.

tion is very great and the damage to the animal may be fully equal to that caused by scab."

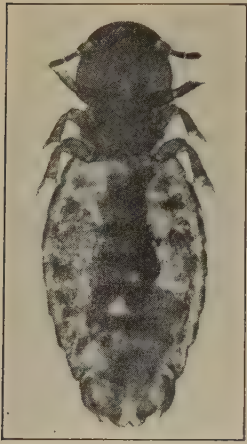

FIG. 50.—Biting louse of the Angora goat, *Trichodectes hermsi*. × 22.

Horses, mules and asses, but horses more particularly, when poorly or irregularly groomed may suffer from two species of biting lice, *Trichodectes parumpilosus* Piaget and *Trichodectes pilosus* Giebel, of which the latter according to Kellogg and Ferris[1] has not been reported from North America although it is reported by Hall[2] on horses in Michigan. *Trichodectes parumpilosus* is described by Osborn,[3] viz.: "The head is decidedly rounded in front, the antennæ inserted well back, so that the head forms a full semicircle in front of the base of the antennæ. The abdomen is more slender and tapering than in *scalaris*. . . . The color is much as in the allied species, the head, thorax and legs being a bright reddish brown, or chestnut, and the abdomen of a dusky yellowish color, with about eight transverse dusky bands occupying the central or anterior portions of the segments and extending from the middle line a little more than halfway to the margin. They are hardly as conspicuous as in *scalaris*." *T. pilosus* is a smaller species and the antennæ are inserted well forward, almost on a line with the anterior border. Hall states that these "lice give rise to itching, and the results from this are often surprisingly unpleasant. A barn full of horses may become a pandemonium as a result of lice. The itching animals attempt to relieve the itching by rubbing and biting, other animals start to kick, presently the kicking becomes general and there is a resultant clamor and din, with a substantial element of danger to the horses and attendants." The life history is about the same as for the biting cattle lice.

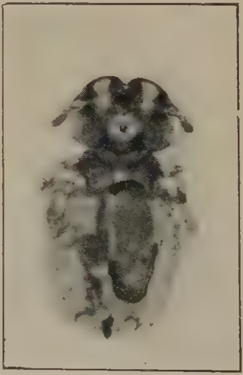

FIG. 51.—The biting dog louse, *Trichodectes canis*. × 35.

Sheep may at times show severe infestations of *Trichodectes ovis* Linn. (= *T. sphærocephalus* Nitzsch). This species is about 1.5 mm. in length, the head being somewhat rounded and as long as broad and reddish in color, the abdomen is whitish. Because of extensive dipping operations against scab this louse has seldom had an opportunity to thrive, but we have observed that when scab had disappeared and consequently no dipping was done, the biting lice appeared in troublesome numbers.

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[1] Kellogg, V. L., and Ferris, G. F., 1915. The Anoplura and Mallophaga of North America. Leland Stanford Junior University Publications (May 25, 1915), 74 pp. + 8 plates.

[2] Hall, M. C., 1917. Notes in regard to horse lice. *Trichodectes* and *Hæmatopinus*. Journ. Amer. Vet. Med. Assoc., Vol. LI, N. S., Vol. 4, No. 4, pp. 494-504.

[3] Osborn, Herbert, 1896. Insects affecting domestic animals. U. S. Dept. of Agric., Div. of Ento., Bull. No. 5, N. S., 302 pp.

Goats are very commonly enormously infested with biting lice. Several species from goats have been described and about which there is still some confusion but the common species is *Trichodectes capræ* Gurlt (= *T. climax* Nitzsch). The author has found Angora goats to be heavily infested with *Trichodectes hermsi* Kellogg and Nakayama (Fig. 50), which resembles *T. penicillatus* Piaget, which in turn is said to be a synonym of *T. limbatus* Gerv., of *T. crassipes* Rudow and *T. major* Piaget. The irritation produced by the lice particularly on Angora goats causes the animals to rub or bite themselves so much that the mohair is matted and pulled out resulting in considerable loss. The individual hairs are weakened by the gnawing of the lice.

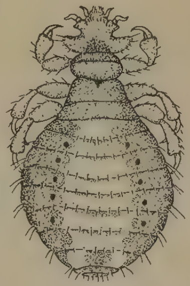
FIG. 52.—A biting louse of the guinea pig, *Gyropus ovalis*. (Redrawn after Osborn.) × 35.

Dogs, particularly puppies, may suffer much irritation from a small biting louse, *Trichodectes canis* De Geer (= *T. latus* Nitzsch) (Fig. 51). It is a broad, short species, measuring about 1 mm. in length. The author has also taken biting lice from a dog in Berkeley, Calif., which were described as *Heterodoxus armiferus* n. sp. by Paine.[1] As this genus is said to be restricted to the kangaroo the incident is interesting.

Cats may become heavily infested with *Trichodectes subrostratus* Nitzsch. *Guinea pigs* commonly harbor two species, *Gyropus ovalis* Nitzsch (Fig. 52) and *Gliricola porcelli* Linné (= *Gyropus gracilis* Nitzsch) (Fig. 53). The llama harbors *Trichodectes breviceps* Rudow. *Trichodectes tibialis* Piaget (Fig. 54) is exceedingly abundant on California deer.

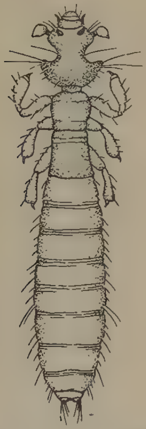
FIG. 53.—A biting louse of the guinea pig, *Gliricola porcelli*. (Redrawn after Osborn.) × 35.

Control of Biting Lice of Mammals.—Sodium fluorid as employed for the control of lice on poultry (dusting method) has proved effective in the destruction of the biting lice on cattle, horses, goats, sheep, dogs, cats (light treatment) and guinea pigs. Bishopp states that "a high degree of effectiveness (90 to 100 per cent destruction) may be obtained by applying the sodium fluorid with a dust gun to the flock in a pen as the goats are driven through a chute. It does not seem to be necessary to drive the dust into the mohair especially and only a small amount,—about one-third ounce per head—is necessary."

[1] Paine, J. H., 1912. The Mallophagan genus Heterodoxus Le Souëf and Bullen. Entomological News, Vol. 23 (Oct.), pp. 359-362. [This is now considered as a synonym of *Heterodoxus longitarsus* (Piaget)—Author.]

The following suggestion by Lamson[1] for the treatment of cattle lice in general is particularly noteworthy:

> "Of the many different measures for the control of lice on *dairy cows* and *young stock, raw* linseed oil gave the best results from the standpoint of economy of material and labor of application, killing all the lice but not injuring the skin and at the same time not making it necessary to thoroughly drench the cow. It has no poisonous properties. At the same time it is a logical remedy as the lack of oiliness in the skin of the cow is a fundamental reason for her being lousy. Linseed oil can be put on at the time taken for grooming or cleaning the cows, thus doing two things in one application. . . . From four to five cows can be treated with a pint . . . treatment should be repeated at least five times. Raw linseed oil can be best applied with a brush having bristles of unequal length. Do not rub the skin too vigorously when applying the oil. Do not allow the animals that have been treated to go out in the strong sunlight until at least twelve hours after applying the oil. Do not exercise the animals after the treatment. Do not use the boiled or refined linseed oil."

Linseed oil as already suggested is effective against both kinds of lice, while sodium fluorid is useful against biting lice only. As a rule effective standard dips, made of kerosene, nicotin, arsenic, cresol, etc., as recommended later in this chapter, will give good results for all lice, but because of the simplicity of application and low toxic action of sodium fluorid to domesticated animals and man, it is worth while determining whether the lice are Mallophaga or not.

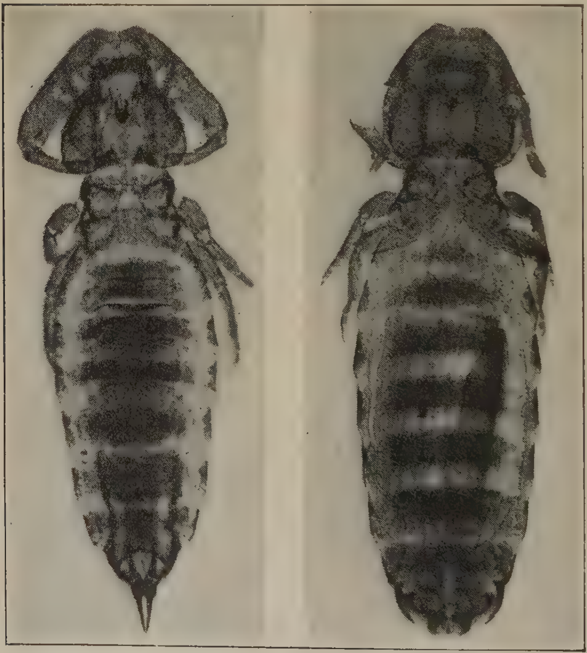

FIG. 54.—A biting louse of deer, *Trichodectes tibialis;* male, left; female, right. × 31.

It has lately been found by Wells, Bishopp and Laake (loc. cit.) that a dust compound of derris root (supposedly *Deguelia* (*Derris*) *elliptica*) and a carrier such as flour (equal parts) is effective against both biting and sucking lice.

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[1] Lamson (*loc. cit.*).

B. The Sucking Lice

Order Anoplura

Relation to Mallophaga.—The sucking lice have held various positions in their systematic relation to other insects, but within the past few years there is a strong tendency to place them in a separate order, Anoplura. A few taxonomists believe them so closely related to the biting lice that both groups of lice are placed in the same order, viz., Anoplura, with the Mallophaga (biting lice) reduced to a suborder and the sucking lice placed in the suborder Siphunculata. There is little to support the arrangement of these parasites under a suborder (Parasita) of the Hemiptera.

With the general characteristics of the Mallophaga well in mind together with the fact that the sucking lice have a protrusible piercing proboscis, as before stated, and that they are restricted to mammals, a general review of their classification may be undertaken.

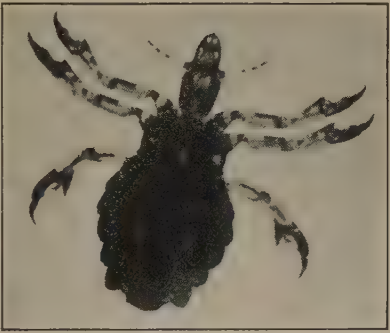
FIG. 55.—Hog louse, *Hæmatopinus* (*urius*) *suis.* × 7.

Classification.—In his catalogue and host list of the Anoplura for 1916 (Proc. Calif. Acad. Sc., Vol. VI, No. 6, pp. 129-213) Ferris lists 120 species which are divided into four families, viz.: (1) Echinophthiridæ, with body thickly beset with more or less short, stout spines, or with spines and scales; antennæ four- or five-segmented, spiracles small, occurring exclusively on marine mammals, e.g., *Antarctophthirius trichechi* (Boh.) from the Pacific Walrus, and *Echinophthirius phocæ* (Lucas) from the seal; (2) Hæmatomyzidæ, with "body spines or hairs always in definite rows, never with scales, head tubularly produced anteriorly, tibiæ without a thumb-like process opposing the claw, antennæ five-segmented"; e.g., *Hœmatomyzus elephantis* Piaget from African elephants; (3) Hæmatopinidæ, body spines or hairs as for 2 above, head not tubularly produced anteriorly, tibiæ with thumb-like process opposing the claw, eyes lacking, antennæ three- or five-segmented, e.g., *Hœmatopinus suis* (Linn.) from swine, and *Linognathus piliferus* (Burm.) from dogs; (4) Pediculidæ, body spines or hairs and thumb-like tibial process as for 2 and 3 above, "eyes present and well pigmented, antennæ five- or three- obscurely five-segmented," parasitic on man, apes and monkeys, e.g., *Pediculus corporis* De Geer, body louse of man, and *Pedicinus rhesi* Fahrenholz from the rhesus monkey.

Sucking Lice Affecting Domesticated Mammals.—The sucking lice of the domesticated mammals belong to the family Hæmatopinidæ and are arranged mainly under two genera, Hæmatopinus and Linognathus. *Swine* have one species of louse only, *Hœmatopinus suis* (Linn.) = *H. urius* Nitzsch (Fig. 55). This is the largest representative of the entire group, measuring as much as 5 to 6 mm. in length and is a cosmopolitan species. Next to cholera this louse is said to be the hog's worst enemy. These parasites occur chiefly in the folds of the skin on the neck, at the base of and inside the ears, along the belly and on the inner sides of the legs. According to Florence[1] hog lice feed readily on man but will not feed on guinea-pigs. The same author summarizes the life history at 35° C., continually next to body in vials as follows, incubation period of eggs (Fig. 56), 13 to 15 days, first molt after 5 to 6 days, second molt after 4 days, third and last molt after 4 to 5 days, sexual maturity after 3 days, or a total of 29 to 33 days from egg to egg. It will be seen that this is a considerably longer time than is required for the life history of any of the biting lice or Mallophaga, a matter to consider in the application of control measures.

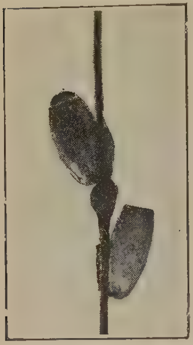

Fig. 56.—Nits or eggs of the hog louse attached to the hair of the host. One of the eggs has hatched. × 10.

Three species of sucking lice occur on *cattle,*—*Linognathus vituli* (Linn.) commonly known as the long-nosed ox louse or "blue louse," measuring about 2 mm. in length and distinguished from the next species by its long nose and slender body (Fig. 57); and *Hœmatopinus eurysternus* Nitzsch or short-nosed ox louse (Fig. 58), which is somewhat larger than the former and much broader in proportion; *Solenopotes capillatus* Enderl., has recently been redescribed by Bishopp[2] as of wide distribution in the United States and as a serious cattle pest at times; it measures from 1.2 to 1.5 mm. in length and in general appearance apparently resembles the short-nosed ox louse. All three species show a tendency toward attachment on the head, neck and shoulders of the host where the eggs are attached to hairs. The eggs of the short-nosed louse are said to be white, those

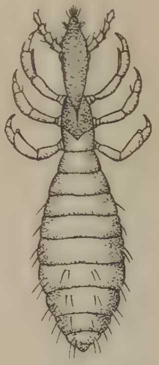

Fig. 57. — The long-nosed ox louse, *Hœmatopinus vituli.* (Redrawn after Osborn.) × 30.

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[1] Florence, Laura, 1921. The hog louse, *Hœmatopinus suis* Linné: its biology, anatomy, and histology. Cornell University Agricultural Experiment Station Memoir 51, pp. 641-743.

[2] Bishopp, F. C., 1921. *Solenopotes capillatus,* a sucking louse of cattle not heretofore known in the United States. Journ. Agric. Research, Vol. XXI, No. 11, pp. 797-801.

of the long-nosed louse as nearly black, and those of the Solenopotes as pale yellowish. The incubation period ranges from 7 to 12 days according to various observers, and the life history from egg to egg from 22 to 27 days. Lamson[1] reports that the short-nosed ox louse lays from 35 to 50 eggs over a period of from 10 to 15 days.

Horses, mules and asses are frequently infested more or less with one species of sucking louse, *Hæmatopinus asini* (Linn.) = (*H. macrocephalus* Burm.),—it measures from 2.5 to 3.5 mm. in length; it resembles the hog louse except that the head is relatively longer and more robust. The lice are usually located at the base of the mane and forelock and root of tail. Hall[2] reports that 22 out of 38 horses examined were infested with this species. The same author reports the incubation period for the egg to range from 10 to 19 days (eggs kept in Petri dishes at from 21° to 31° C.). It is quite probable that this species requires about the same time as the hog louse for the completion of its life history, i.e., from 29 to 33 days from egg to egg.

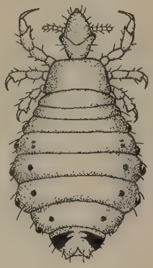

FIG. 58. — The short-nosed ox louse, *Hæmatopinus eurysternus.* (Redrawn after Osborn.) × 22.

Sheep are in some parts of the United States affected by the so-called foot louse, *Linognathus pedalis* (Osborn). The author has observed this species on sheep from California and Nevada and Osborn has reported it from Iowa. It occurs on the legs, especially in the region of the dew claws, but we have found that in heavy infestations it may actually invade the wool above the knee, and deaths have been reported as due to this louse. This species measures about 2 mm. in length and as it is the only sucking louse likely to attack sheep in the above manner, its identity can be easily established. *Linognathus ovillus* (Neum.) is reported as the sucking louse of sheep in Scotland and New Zealand.

Goats often suffer heavy infestations of *Linognathus stenopsis* (Burm.). *Dogs* are commonly heavily infested with *Linognathus piliferus* (Burm.), and *rabbits* harbor *Hæmodipsus ventricosus* (Denny).

Control of Sucking Lice of Mammals.—Poorly-fed animals, crowded pens and unsanitary quarters are factors in the multiplication of lice, but the parasites may gain a foothold in spite of plenty of food, clean quarters and adequate space, hence the up-to-date stock farmer should not neglect to install a good dipping vat as a part of his equipment. Although lice will not breed away from their host, they may drop off with hair and may remain alive for probably not over five days and the same animals after dipping or other animals of the same species introduced into quarters before the dropped lice have died, may become reinfested. Furthermore, the great majority of the ordinary dips do not destroy the eggs present at the time of treatment, hence a second dipping is usually necessary after the young lice have hatched. This second dipping should be properly timed and in most cases should be done 16 to 18 days after the first. The author has found that concrete hog wallows containing water to which a film of crude oil is applied, afford very satisfactory results in the control of the hog louse. The wallow should be shallow and built in the shade of a tree or otherwise protected from the sun so as to protect the pigs from oil burns.

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[1] Lamson, G. H., Jr., 1918. *Loc. cit.*

[2] Hall, M. C., 1917. *Loc. cit.*

Both the biting and sucking lice of cattle, horses and other animals may be controlled through the repeated use of *raw* linseed oil applied by hand using a brush as already explained, but the animals must be kept out of the sun for 10–12 hours. In fact any of the effective dips may be successfully applied in this manner or also by means of an ordinary spray pump, provided the animal is given a thorough wetting. Among the dips used for lice are the following, (1) *kerosene emulsion,* prepared and used as described in the chapter on ticks; there is some danger from burns; (2) *arsenical dips* also prepared and used as described for ticks; its poisonous properties must be considered; (3) *nicotin dips,* containing 0.05 per cent of nicotin. Plans for the construction of a dipping vat together with method of procedure in dipping may be found in a later chapter dealing with ticks.

For the handling of smaller animals such as dogs, cats, monkeys, etc., we have found a small tub or pail very useful and a dip made of a 2 per cent solution of creolin. The water should be soft and lukewarm. Clear cool water should be at hand to bathe the face and eyes after the animal has been given a complete plunge. The use of a derris root dust as described for the control of biting lice is also recommended not only for smaller animals but cattle as well. There are some excellent dips particularly coal-tar on the market which should be used as directed, but there are also numerous dips that can not be recommended.

Fumigation for lice is seldom practiced, but it is interesting to know that Osborn[1] in 1896 successfully used fumigants in the control of the short-nosed ox louse. In his experiments the animal was placed in a tight box stall, one end having a close-fitting door to admit the largest animal to be treated, the opposite end a stanchion in which the animal is fastened. An opening at the stanchion end of the stall is made for the animal's head to protrude, and is surrounded by a sack-like covering open at both ends, the inner end nailed to the opening and the other made to fit tightly around the head just in front of the horns, thus exposing the eyes and nose to the air. The fumigating substance is introduced into the stall through an opening at the side near the bottom. He used tobacco, which was placed on a wire screen over a tin trough containing alcohol. He states that it should, however, be burned with coals or by using a small quantity of kerosene. One or two ounces of tobacco and an exposure of 20 to 30 minutes was found effective. Moore[1] in 1916 reported some suggestive experiments with nitrobenzene, in which he freed a hog of lice, a sheep of louse flies, a dog of fleas and experiments with sundry rats, guinea-pigs, cow, etc., by placing them in a fumigating box. Sufficient nitrobenzene was introduced to produce a saturated atmosphere, i.e., about two to three drops per cubic foot of air. The fleas left the dog in half an hour, dying in an hour and a half, the lice on the hog were killed in 6 to 8 hours and ninety per cent of the louse flies left the wool of the sheep in 12 hours, some of them, however, reviving. No injurious effects were discovered in the animals fumigated for the period noted. An exposure of ten to twelve hours killed a cat but did not injure guinea-pigs.

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[1] Osborn, Herbert, 1896. *Loc. cit.*

Lice Affecting Man and Monkeys.—The three species of lice occurring on man belong to the family Pediculidæ (antennæ five- or three-segmented; eyes present, distinctly pigmented; legs fitted for climbing, the tibiæ with a thumb-like process opposing the claw; no pretarsal sclerite between tibia and tarsus)[2] which is divided into two subfamilies, (A) Pediculinæ (antennæ five-segmented; no pleural plates), inclusive of the genus Pediculus (head short, legs all of approximately the same size, abdomen elongated, spiracles small, abdominal segments without lateral projections, and with numerous small spines), e.g., *Pediculus capitis* De Geer, the head louse of man; *Pediculus corporis* De Geer (= *P. humanus* Linn. = *P. vestimenti* Nitzsch) the body louse of man; *Pediculus consobrinus* Piaget reported from *Ateleus paniscus* and believed to be doubtfully distinct from *P. capitis;* and the genus Phthirius (anterior legs much smaller and with much slenderer claws than the others, abdomen short and broad, the fifth to eighth segments with conical lateral processes, spiracles large, those of the first three abdominal segments crowded close together), including only one species, *Phthirius pubis* Linn. (= *Phthirius inguinalis* Leach) the pubic louse or crab louse of man. The other subfamily (B) Pedicininæ, antennæ three-segmented or obscurely five-segmented, head more or less elongated, abdomen with a single row of many very small spines on each segment, pleural plates present on certain abdominal segments, includes two genera found on monkeys, e.g., *Pedicinus breviceps* Piaget, from *Lasiopyga mona,* and *Pedicinus eurygaster* (Burm.) from *Pithecus nemestrinus,* and *Phthirpedicinus micropilus* Fahrenholz from *Pithecus rhesus.*

The human head louse, *Pediculus capitis* De Geer (Fig. 59), is gray in color, but is said to vary according to the color of the hair and color of the host. (Murray.[1]) The male averages nearly 2 mm. in length and the female nearly 3 mm. This species occurs on the head, about the ears and occiput, but from reliable observations made by a number of observers it may establish itself on other hairy parts of the body. In severe infestations the hair may become literally matted with eggs (nits), parasites and exudate from the pustules which originate from the louse bites. The term *plica palonica* is applied (Stiles) to the fetid mass, consisting of exudate forming a sort of carapace (*trichoma*), in which fungus may develop, and beneath which myriads of lice may be found.

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[1] Moore, William. 1916. Fumigation of animals to destroy their external parasites. Journ. of Econ. Ento., Vol. 9, No. 1, pp. 71-80.

[2] The taxonomic characters here used are taken from Ferris, 1916 (*loc. cit.*).

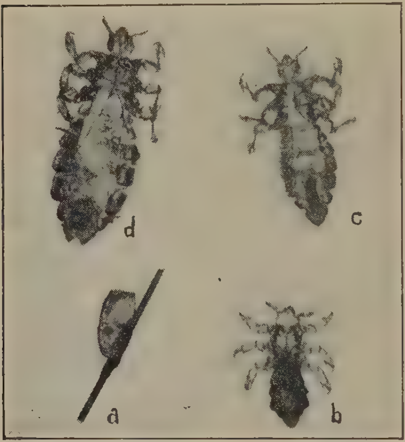

FIG. 59.—Life history of the human head louse, *Pediculus capitis*. *a.* egg; *b.* larva; *c.* male; *d.* female. × 10.

The number of eggs deposited by the female ranges from 50 to 150. These are glued to the hairs and hatch in from 5 to 10 days, averaging about 7 days. Development is very rapid, 3 weeks usually covering the entire life history from egg to egg.

Treatment for Head Lice.—Lice are easily disseminated, hence slight infestations may occur under the best of conditions, particularly among schoolchildren. However, the continued presence of lice on head or body is inexcusable. Personal cleanliness is the best safeguard. The mere use of water in washing the head is ineffective in destroying vermin present in the hair, and the nits are not easily destroyed even with chemicals. The simplest method of eradication is to clip the hair, catching the hair in a bag and burning it, and then applying a wash consisting of equal parts of kerosene and vinegar or acetic acid. Mixing the kerosene with olive oil lessens the possibility of irritation. The head should be thoroughly washed in an hour or two with hot water and plenty of soap. If nits are still found after this treatment, a second application should be made in a day or two.

The use of a fine comb dipped in kerosense gives good results. The oil coming in contact with the lice kills them, but the eggs are not destroyed, hence the combing must be repeated three times at intervals of one week in order to destroy the newly hatched young and thus prevent further propagation. The combings should be carefully disposed of by burning or dropping in kerosene to prevent further spread.

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[1] Murray, Andrew, 1860. On the pediculi infesting the different races of man. Trans. Roy. Soc. Edinb., T. 22, p. 567. Cited by Osborn.

Washing the head with a 2 per cent solution of creolin is also effective if repeated as suggested above. Using a long towel wet with a 10 per cent solution of tincture of larkspur (Delphinium), as a turban about the head is an effective method. The heads of children with long hair may be treated successfully in the following manner as described by Whitfield in the Lancet (Dec. 14, 1912). The child is placed on its back in a bed, with the head hanging over the edge, so that the hair falls in a basin resting on a chair. The solution to be used (phenol 12 grams and water 500 grams) is poured over the hair and carefully washed back and forth for a period of ten minutes until the hair is well soaked, particularly back of the ears and the nape of the neck. Afterwards the hair is drained, not wrung out however, and is then put up with a towel or flannel cloth in turban fashion. After an hour the hair may be washed out or simply left to dry, when it will be found that all the pediculi as well as the ova have been destroyed.

The pubic louse, *Phthirius pubis* (Fig. 60), is easily recognized by its crab-like appearance. It measures from 1.5 to 2 mm. in length and is nearly as broad as long and is grayish white in color. It infests the pubic regions particularly but also the armpits and more rarely other parts of the body such as the mustache, eyelashes and eyebrows. The writer has seen soldiers infested with this species of louse from the ankles to the neck. These lice are remarkably stationary in their habits, often remaining attached for days at one point with mouth parts inserted into the skin. The pruritis caused by the bites of these parasites is very intense and a discoloration of the skin usually results if infestation continues over a longer period of time. The term *phthiriasis* may be employed to designate infestations of pubic lice, although the term *pubic pediculosis* is also used.

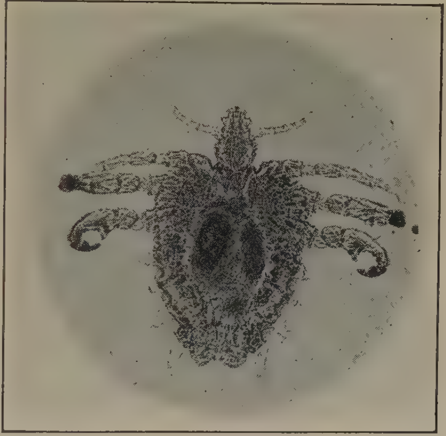

FIG. 60.—The pubic louse, *Phthirius pubis.* × 23.

The female louse deposits its eggs on the coarser hairs of the body where the parasites occur. The number of eggs deposited per female is apparently quite small, although Nuttall[1] states that he would not be surprised to learn that 50 or more eggs may be laid. The incubation period seems to be from 6 to 8 days. After three molts the adult stage was reached in Nuttall's experiments in from 15 to 17 days, and the egg to egg period 22 to 27 days.

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[1] Nuttall, G. H. F., 1918. The biology of *Phthirus pubis.* Parasitology, Vol. 10, No. 3, pp. 383-405.

Treatment for Pubic Lice.—The pubic lice are rather easily destroyed by rubbing the affected parts with a 10 per cent solution of tincture of larkspur, and repeating the application in about 8 days. Washing the affected parts with hot vinegar to destroy the eggs may make a second treatment unnecessary.

Shaving the hair of the pubic region, axillæ, chest and legs, and then applying a kerosene-vinegar mixture followed by a bath with soap and warm water has given good results. An objection to this method is the irritation produced by the growing hair, particularly to soldiers on the march.

Mercurial ointment is frequently applied as a local ointment but its use may cause a dermatitis, hence the following substitute is recommended, yellow oxid of mercury, 10 parts; salicylic acid, 1 part; and vaseline 90 parts.

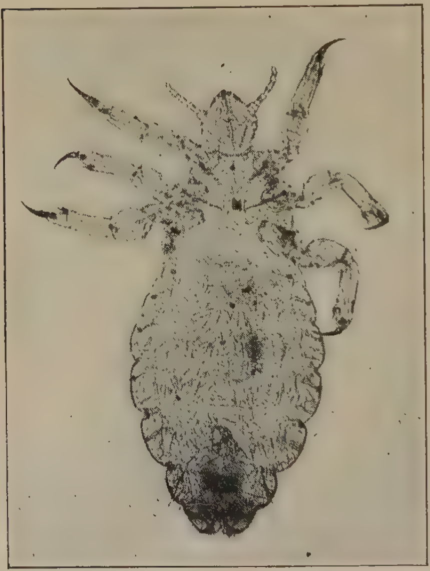

FIG. 61.—Human body louse, *Pediculus corporis.* × 15.

The Body Louse, Pediculus Corporis (Fig. 61), is the common clothing louse which during the great war became known as the "Cootie," also called the "Grayback." Parasitologists now quite generally agree that there is no specific difference between it and the head louse (*P. capitis*). both being regarded as racial forms of *Pediculus humanus.* Evidence concerning this agreement is most convincingly presented by Nuttall,[1] whose admirable treatises on lice and their relation to disease and control should be read by all students interested in the subject.

Body lice infest the clothing where it comes in close contact with the body rather continuously, e.g., the fork of the trousers, armpits, the waist line, neck and shoulders. In his inspection of troops at delousing stations the author usually found lice on the underclothing, but the nits were generally found in the seams of the breeches if present at all. After all clothing was removed lice were occasionally found on the body for which reason bathing and strong rubbing were insisted upon when possible to remove these stragglers. Eggs are undoubtedly by preference deposited on fibers in the seams of clothing as already mentioned. Nuttall and others have satisfactorily proved that the body louse may attach its eggs to the coarser hairs of the body, which may render it necessary to shave such parts in carrying on delousing operations.

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[1] Nuttall, G. H. F., 1917. The biology of *Pediculus humanus.* Parasitology, Vol. 10, No. 1, pp. 80-185.

Nuttall states that a female body louse may lay from 275 to 300 eggs, the average number laid per day being about 10 for 20 to 30 days. The incubation period varies from 4 to 8 days when eggs are kept near the body at about 35° C. Hatching according to Nuttall does not occur when the temperature reaches 22° C. or below; a favorable temperature being attained at about 25° C. but with a slow development, lasting 16 days, and at 30° C. hatching was observed to occur in from 7 to 14 days, mostly in 11 to 13 days, at 38° C. hatching was slightly retarded and at 40° to 45° C. the eggs did not hatch. The effective zone for the egg stage is apparently from about 20° C. to 40° C. The optimum temperature for egg deposition is said to be about 32° C. ceasing at 20° C.

The young lice begin sucking blood at once on hatching from the eggs and throughout their development feed frequently both day and night particularly when the host is quiet. Maturity may be reached in 16 days from the time the eggs are deposited. Unfed lice soon die, probably 10 days would cover the longest period of fasting. However, if fed, lice may live from 30 to 40 days.

The following instructive summary concerning temperature influences on lice is given in a lecture on the "Life History of the Human Louse," by Pierce,[1] June 17, 1918:

> "In the absence of definite humidity data we may roughly describe the zones of climatic influence on the lice as follows. The zone of minimum fatal temperatures for eggs is below 20° C. (68° F.) and for adults lies below zero centigrade (32° F.). The zone of dormancy in adults extends from about –10° to 5° C. (14° to 41° F.). The zone of sluggish movement without reproductive activity and with practically no digestive processes extends from 5° to 20° C. (41° to 68° F.). Digestion ceases at 12° C. The zone of optimum activity lies between 20° and 40° C. (68° to 104° F.) with the optimum about 30° C. Practically all egg hatching occurs within this zone, as does all oviposition, practically all assimilation of food, and all normal activity. From 40° to 44° C. the lice are wildly active; this zone represents one of exhaustion in which death of eggs occurs. Above 44° C. (112° F.) lies the zone of maximum fatal temperatures."

Relation to Disease.—The presence of lice on any part of the body causes itching and is very annoying and may be designated as *pedic-*

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[1] Pierce, W. Dwight, 1918. Proceedings of the class formed to study the entomology of disease, hygiene and sanitation. (Mimeograph copy received from author.)

ulosis. That louse bites may produce certain systemic disturbances, seems to be indicated in a report made by Moore,[1] viz.:

> "I started feeding about 700 to 800 twice a day. Almost immediately a general tired feeling was noticed in the calf of the legs and along the shin bones, while on the soles of the feet and underneath the toes this tired feeling was so intense as often to prevent sleep until late in the night. An irritable and pessimistic state of mind developed. An illness resulted with symptoms very similar to grip and a rash similar to German Measles was present, particularly over the shoulders and abdomen."

The skin of persons who continuously harbor lice becomes hardened and deeply pigmented, a condition designated as *vagabond's disease* or *morbus errorum.* Experiments conducted by Dewevre (1892) and others prove that lice may carry the causative organisms of both favus (*Achorion schœnleini* Lebert) and *tropical impetigo* (*Diplococcus pemphigi contagiose* Wherry). Nuttall (1898, *loc. cit.*) states that Dewevre "removed ten pediculi from a child suffering from impetigo and placed them on a healthy infant, which a few days later developed impetigo. The experiment was repeated several times with the same results. In a second series of experiments, he took scrapings from under the nails of children that had impetigo and placing them on artificially scratched places, reproduced the disease. Lastly he took pediculi from a child that was not affected with impetigo and placed them on a child that had the disease; removing them after twenty minutes, he replaced them on a healthy child. The latter acquired the disease, as did fifty per cent of the children so experimented with. He claims the specific microörganism adheres to the front legs especially, also to the hairs of the insect, and the latter carries them as bees do pollen. In the last set of experiments, he only allowed the pediculi to remain half an hour on the healthy head, but this was sufficient to produce infection." The above typical example also illustrates the methods used to secure the experimental evidence of transmission.

Asiatic Relapsing Fever was shown to be louse borne by Mackie[2] in 1907. He records an outbreak of this disease among schoolchildren, in which 137 out of 170 boys and 35 out of 114 girls were attacked. Twenty-four per cent of the lice removed from the boys contained spirochætes (*Spiroschaudinnia* (*Spirochæta*) *carteri* Mackie) while only 3 per cent of the lice removed from the girls were infected. As the parasites increased in abundance among the girls, so also did the epidemic increase, and conversely as the parasites became less abundant among the boys, so also did the epidemic decrease. The spirochætes (Fig. 62) were observed to multiply in the intestine of the lice and were found to be present in the ovaries, testes and Malpighian tubules. Mackie concluded that infection might be spread by the lice by regurgitating the spirochætes into the wound produced by the bite.

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[1] Moore, W., 1918. An interesting reaction to louse bites. Journ. Amer. Med. Assoc., Nov. 2, Vol. 71, pp. 1481-1482.

[2] Mackie, F. P., 1907. The part played by *Pediculus corporis* in the transmission of relapsing fever. British Med. Journ., 1907, p. 1706.

Later (1912) Nicolle, Blaizot and Conseil[1] failed to transmit the spirochætes through the bites of infected lice, and found that the only reliable successful experiments involved the injection or subcutaneous inoculation of an extract of infected lice.

Based on experiments in which men and monkeys were exposed to hundreds of bites, Nicolle and his colleagues came to the conclusion that transmission is brought about by the introduction of spirochætes received under the finger nails and on the finger tips from crushed parasites, which are inoculated into excoriated skin in scratching. They also found that the spirochætes disappear and later reappear, only a few remaining in the insect's intestine up to 5 or 6 hours after infection, and none after 24 hours, but reappear in the insect in from 8 to 12 days and are then present in the general body cavity, none being found in the alimentary canal. It was found that the spirochætes were transmitted to the offspring of infected lice.

The incubation period in the human is said to be from 6 to 8 days. It is stated by Nuttall that a single infective louse, crushed upon the excoriated skin has produced relapsing fever.

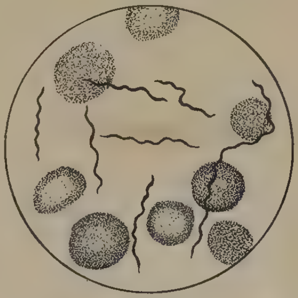

Fig. 62.—*Spirochæta* in a blood smear. (Greatly enlarged.)

Typhus Fever.—Typhus fever, known also as tarbardillo (Mexico), Brill's disease (United States), jail fever or war fever, is a disease of ancient origin and wide distribution. The disease is characterized by a high fever, backache, headache, bronchial disturbances, congested face (designated also as a "besotted expression"), brick-red mottled eruption which later spreads, becoming brownish irregular blotches. This spotting led to the belief that tarbardillo of Mexico was identical with spotted fever of Montana, a fact proved untrue by Ricketts, who lost his life by typhus fever during the course of his investigations. The experiments and observations by Nicolle and Ricketts and Wilder[2] indicate that the bedbug and the flea are not instruments of transmission. That the body louse (*Pediculus corporis*) is probably the sole agent in the transmission of typhus fever has been proved by

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[1] Nicolle, C. N., Blaizot, L., and Conseil, F., 1913. Ann. Inst. Pasteur, March 25, 1913, pp. 204-225.

[2] Ricketts, H. T., and Wilder, R. M., 1910. Further investigations regarding the etiology of tarbardillo, Mexican typhus fever. Journ. Amer. Med. Assoc., Vol. 55, No. 4, pp. 309-311.

Nicolle, *et al.*,[1] (1909, working in Tunis) and Ricketts and Wilder[2] (1910, working in Mexico). The latter found that *Macacus rhesus* can be infected with tarbardillo (Mexican typhus) invariably by the injection of virulent blood from man taken on the eighth to tenth day of fever, that the monkey may pass through an attack of typhus so mild that it cannot be recognized clinically and that immunity results. Typhus was transmitted to the monkey by the bite of the louse in two experiments, the lice in one instance deriving their infection from man and in another from the monkey. Another monkey was infected through the introduction of the feces and abdominal contents of infected lice into small incisions. The causative microörganism of typhus appears to be *Rickettsia prowazeki* da Rocha-Lima (*loc. cit.*)

The incubation period in the human is said to be from 10 to 12 days. The duration of the disease is said to be about 12 days in children, in which it is usually comparatively mild, to 21 to 24 days in adults. The mortality is said to range from 15 per cent to 30 per cent, but may be as high as 50 per cent to 75 per cent under war conditions.

After reviewing the evidence contained in the literature Nuttall[3] states in a summary that the virus of typhus occurs in the blood of affected individuals and that blood collected on the 3rd to the 10th day of the attack has been found virulent. Infection occurs through the bite of infective lice or through such lice crushed upon excoriated skin, and infection may result during 7th to 11th days after the lice have fed on infective blood. If lice are crushed 9th to 10th days after an infective feed, or if their feces are collected 3d to 6th days after they have fed on infective blood, their contents and feces respectively are capable of producing infection if placed upon excoriated skin. It has not been determined how long lice remain infective when once contaminated and the evidence regarding the hereditary transmission of the virus is contradictory.

Trench Fever.—Castellani and Chalmers in their manual of Tropical Medicine give a list of synonyms for Trench Fever, among them, Five-days fever, Volhynian fever, Pyrexia of unknown origin (P. U. O.), Shank Fever, His-Wernerische Krankheit, and Febris quintana.

> "It is characterized by a sudden onset of fever associated with pains:—muscles and bones, particularly in the legs, with especial tenderness of the shins, and lasting twenty-four to forty-eight hours or longer followed by other attacks of fever of less and less severity, separated by apyrexial

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[1] Nicolle, Charles, Comte, C., et Conseil, E., 1909. Transmission experimentale du typhus exanthimatique par le pou du corps. Paris Acad. Sc. Comptes Rendus, T. 149, pp. 486-489.

[2] Ricketts, H. T., and Wilder, R. M., 1910. The transmission of the typhus fever of Mexico (tarbardillo) by means of the louse (*Pediculus vestimenti*). Journ. Amer. Med. Assoc., Vol. 54, No. 16, pp. 1304-1307.

[3] Nuttall, G. H. F., 1917. Lice and disease. Parasitology, Vol. 10, No. 1, pp. 43-79.

intervals of five days' duration (more or less, and ending in complete recovery)" (Castellani and Chalmers).

The causative organism of Trench Fever is believed to be *Rickettsia quintana*, so named by da Rocha-Lima[1] in 1916, confirming the earlier work of Toepfer.[2]

Two Commissions, one British consisting of Byam, Carroll, *et al.*, and the other American, consisting of Strong, Swift, *et al.*, carried out very thorough investigations, during the Great War, and the summary of the findings of the British Commission follows:—

"1. The whole blood from febrile trench fever cases, up to the 51st day of disease, when injected intravenously, is capable of reproducing the disease. The incubation period in such infections varies greatly—from 5 to 20 days.

"2. The virus as contained in the circulating blood is destroyed by the addition of distilled water in large quantities.

"3. The bites alone of infective lice do not produce trench fever.

"4. The excreta of infective lice when applied to a broken surface of skin do readily produce trench fever. The incubation period of such infections is remarkably constant and averages 8 days.

"5. The excreta passed by lice fed on trench fever patients are not infective till the expiration of not less than 5 days from the commencement of the feeding on trench fever blood, thus indicating a development cycle in the louse or a period during which the organism multiplies.

"6. Once lice are infective they remain so till at least the 23rd day from date of their infection.

"7. The virus of trench fever, as contained in infected louse excreta, is capable of withstanding drying at room temperature, exposure to sunlight, keeping for not less than 16 days, and heating to 56° C. for 20 minutes.

"8. 80° C. for 10 minutes destroyed the virus, which is therefore not a spore-bearing organism.

"9. The bodies of infected lice when crushed upon the broken skin are capable of producing trench fever. When lice become so infective remains to be determined.

"9a. Active trench fever blood equivalent to the content of 11 lice does not produce trench fever when rubbed into the broken skin.

"10. Infection probably does not take place by the mouth or by inhalation.

"11. The excreta of lice are not normally capable of producing trench fever.

"12. Trench fever infected lice do not transmit the disease to their offspring.

"13. There is a possibility of some attacks of trench fever being afebrile throughout.

"14. The percentage of individuals naturally immune to trench fever is exceedingly small.

"15. Old age is no bar to infection.

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[1] Da Rocha-Lima, H., 1916. Untersuchungen über Fleckfieber. München. Med. Wochenschr., Vol. 63, No. 39, pp. 1381-1383.

[2] Toepfer, H., 1916. Zur Ursache und Uebertragung des Wolhynischen Fiebers. München. med. Wochenschr., Vol. 63, No. 42, pp. 1495-1496.

"16. Such immunity as results from an attack of trench fever is not permanent, and may only persist for so long as the individual shows evidence of the disease.

"17. Even as late as the 79th day of disease a patient's blood may remain infective, and be capable of infecting lice fed on such a patient while febrile.

"18. The different varieties of trench fever result from differences in the persons infected rather than in the source of infection.

Lice and Tæniasis.—*Dipylidium caninum* Linn. (*Tænia cucumerina*), the double-pored dog tapeworm, is a common parasite of the dog and is occasionally found in humans, especially children. It measures from 10 to 14 inches in length, has long seed-like proglottides and an armored scolex, and has as its larval host the biting dog louse, *Trichodectes canis*.[1] The larva or bladder worm, known as *Cysticercus trichodectes*, has been experimentally produced in the louse by placing ripe crushed proglottides of the tapeworm on the skin of a dog infested with lice.

As has already been explained, the biting lice subsist on epidermal scales, skin exudations and other matter on the skin of the animal. This habit makes it comparatively easy for the louse to become infected by swallowing "eggs." The dog, on the other hand, readily infects itself by devouring the lice which irritate his skin.

Persons, particularly children, while fondling louse-infested dogs may easily become infected by accidentally swallowing lice which contain bladder worms. This is more readily accomplished if the person is eating while handling the dogs.

Combating Body Lice (*delousing*).—The destruction of body lice and their eggs requires more than ordinary care as indicated by the preceding study of their life history and habits, and intelligent cooperation is essential. The presence of lice upon the head and body is no longer to be regarded as simply a sign of good health and vigor.

To avoid becoming lousy several simple precautions are essential: (1) avoid contact with lousy persons and their effects; (2) avoid overcrowding; (3) bathe at least once a week with hot water using a heavy soap lather and rub dry with a rough towel; (4) complete change of underwear at least once a week; to dispense entirely with underwear is to invite lousiness; (5) do not sleep between blankets which were previously used by doubtful occupants of the bed and make sure that the bed linen is really fresh; under typhus-fever conditions, the above precautions must be supplemented by others, namely attendants must wear specially prepared protective clothing and that of patients should be placed at once in a vessel well oiled with kerosene, and the floors of the receiving rooms might well be oiled as an added protection,

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[1] Occurs also in the dog flea, *Ctenocephalus canis*, and in the human flea, *Pulex irritans*.

(6) where possibility of infestation exists, frequent inspection at least once a week of body and clothing is essential.

Much literature has appeared dealing with louse repellents and pediculicides and this subject is admirably treated in Nuttall's comprehensive work on "Combating lousiness among soldiers and civilians," in Parasitology, Vol. 10, No. 4, pp. 411-588 (May, 1918), but little positive evidence concerning repellents is available,—such materials as oil of eucalyptus, anise, and cloves, naphthalene and carbolic acid do have some repellent effect. N. C. I. powder, consisting of commercial naphthalene 96 per cent, creosote 2 per cent, iodoform 2 per cent, dusted over underclothing once a week has a killing effect, but it must be borne in mind that naphthalene is irritating.

Fumigation of clothing, persons to be properly bathed while this is being done, offers a quick means of louse destruction, but requires specially constructed sealed chambers (vacuum necessary in some cases) either stationary or portable. Fumigants do not as a rule destroy the nits hence can only be regarded as temporary and the treatment must be repeated periodically. Among the gaseous substances used for this purpose are the following: (1) *hydrocyanic acid gas,* which according to Pierce (1918, *loc. cit.*) is generated in an air-tight generator using 2½ parts of sodium cyanid solution made by dissolving 4 pounds of sodium cyanid in 1 gallon of water, 1 part of sulphuric acid (commercial) and 1 part of water, and piped into the fumigation chamber. Pierce directs, viz.:—"Create 25 inch vacuum. Generate gas 5 minutes in generator. Wash into fumigation chamber. Break vacuum so as to fumigate in normal atmospheric pressure 25 minutes. Remove gas by producing 25 inch vacuum. Return to normal pressure. Open door slightly and run vacuum pump a few minutes." It must always be borne in mind that this is a very dangerous gas and must not be used by inexperienced persons. (2) *Carbon tetrachlorid* does not require complicated apparatus and its use is described by Foster[1] viz.:—

> "A 10-gallon tin can such as is used for shipping liquid disinfectants was obtained. This can was 12 inches in diameter, 19 inches high, sheathed with a light wood covering, and weighed 5½ pounds. The top was cut out so that clothing could be introduced and removed readily. In making the tests the complete clothing of a United States Army private, consisting of hat, olive-drab woolen blouse, olive-drab woolen breeches, leggins, socks, woolen underdrawers, woolen undershirt, and olive-drab shirt, was placed in this can each article being firmly rolled up. A soiled shirt, badly infested with lice, was cut into four pieces. Each piece of the shirt was rolled fairly tightly and then further wrapped in 10 thicknesses of ordinary sheeting. One piece of this material containing 90 live lice was lightly wrapped in the olive-drab breeches and placed near the bottom of the container, another holding 98 live lice was tightly wrapped in the middle

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[1] Foster, M. H., 1918. Preliminary report on carbon tetrachloride vapor as a delousing agent. U. S. Public Health Reports, Vol. 33, No. 43, pp. 1823-1827.

of the blouse and packed near the top of the contents. The complete outfit of wearing apparel was placed in the tin and pressed down rather firmly, occupying a little more than one-half of the total space. Several layers of filter paper were laid on top of the clothing, and on this paper 25 cc. of carbon tetrachloride was poured. The top of the can was covered by several thicknesses of toweling and a loose cover placed over this, the idea being to protect the can from the effects of drafts but not to seal it hermetically so as to permit some of the air to escape at the top when it was displaced at the bottom by the heavy vapor. At the end of two hours the can was opened, the package containing the lice-infested shirt was aired and examined. All the lice were found to be dead and they did not revive when examined at various periods up to 24 hours afterwards. It was ascertained that exposure, under similar conditions, to the same strength of carbon tetrachlorid for an hour and a half was not sufficient to kill all the lice, about 25 per cent surviving. It was also found that a lesser amount of carbon tetrachlorid was not sufficient to kill the lice in two hours.

"These experiments were repeated in various ways with lice on pieces of cloth contained in test tubes open at both ends but fairly tightly sealed with cotton plugs. These tubes were tightly wrapped in all the various articles of clothing and it was found that 25 cc. of carbon tetrachloride, with exposure of two hours, was sufficient to kill all the lice. . . . The garments were hung up and aired for an hour, after which no odor of carbon tetrachlorid could be detected on them. . . . The tests were made at temperatures ranging from 68° to 72° F. . . . In considering the applicability of carbon tetrachlorid as a delousing agent, the possible danger to human life must be borne in mind. The substance is said to be slightly more poisonous to human beings than chloroform."

(3) *Chlorpicrin* is highly recommended by Moore and Hirschfelder,[1] whose careful and comprehensive investigations concerning lice deserve much praise. The following account of their experiments with this gas will also assist the student in understanding methods employed in this type of investigation. They write:

"In a study of the toxicity of a large number of chemicals it was found that chlorpicrin, or nitrochloroform (CCl_3NO_2), although quite volatile possesses a very high toxicity. This high toxicity is due, in a large measure, to the ability of the chitin to absorb from the air even minute quantities of the chemical and to permit it to pass through into the insect's body. In studies dealing with the fumigation of grain and flour, chlorpicrin showed great penetration. Experiments were therefore conducted to determine its value in the fumigation of clothing to destroy lice and their eggs. Inasmuch as under field conditions only the simplest apparatus is available for the work, the fumigations were carried out in an ordinary galvanized iron ash can, without special efforts to make it air tight. Chlorpicrin of the desired quantity was poured upon the garments, while they were being packed in the can, thus insuring a more rapid evaporation and penetration. The results of these experiments show that to evaporate the chlorpicrin rapidly in order that it may penetrate all parts of the clothing and destroy the eggs of the lice within 30 minutes, a small amount of heat is necessary. Three one-liter flasks filled with water heated to 80° to 85° C. were found to answer the purpose. In practice the box might be heated or hot stones might be used in the same manner as the flasks. Where no heat was available, a longer exposure is necessary. The active stages are more easily destroyed than eggs; hence in only two experiments were active stages used. They were placed in vials closed with gauze and the vials placed in pockets of the trousers in folds of the cloth, and in one case wrapped in three thicknesses of heavy underwear and placed in a leather ax case which was then strapped shut. The lice were in all cases killed.

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[1] Moore, W., and Hirschfelder, A. D., 1919. An investigation of the louse problem. Research Publications of the University of Minnesota, Vol. VIII, No. 4, 86 pp.

"Inasmuch as chlorpicrin is used in gas warfare, a supply should be available on the fighting front. Owing to its poisonous nature, and its irritating effect on the eyes, nose, and throat, it would be necessary for the operator to use a gas mask. Airing the clothing in the open for 3 to 5 minutes is sufficient to remove the chlorpicrin, after which the clothing can be worn.

"No bleaching or fading of colored fabrics was observed in a number of tests made with fabrics of delicate coloring, providing the chlorpicrin contained no impurities of chlorine or nitrogen peroxide. No injurious effect on leather was observed, but rubber is injured somewhat, although not as much as might be expected.

"The use of chlorpicrin is recommended as a means of delousing garments under conditions prohibiting the use of hot air or steam, since no particular apparatus is needed for the work. Chlorpicrin is superior to other chemicals recommended for fumigation since, on account of its extreme toxicity, high volatility, and ability to penetrate through masses of clothing, a high temperature is not necessary to insure the destruction of both eggs and active stages of the lice in a short period of time."

Laundry methods as a means of delousing have given good results when properly employed. Moore [1] reports that in the washing of rough cotton goods at 180° F. (82.2° C.) for 30 minutes, lice and their eggs are destroyed and that if by chance eggs should escape destruction in the washing process they would later be destroyed during drying in the hot-air tumbler. Woolens must be treated somewhat differently in order to avoid shrinkage as shown by the work of Pierce, Hutchinson and Moscowitz,[2] viz.:

"1*a*. In the washer, run a current of live steam fifteen minutes, revolving cylinder every five minutes, and discharging water of condensation every five minutes. Remove the garments and shake until almost dry. This requires only a few shakes.

"1*b*. Submerge in water at 165° F. for twenty minutes without motion, except a few revolutions every five minutes.

"2. Wash fifteen minutes at 131° F. in heavy suds and light load.

"3. Rinse three times, three minutes each, at 131° F.

"4. Extract.

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[1] Moore, William, 1918. The effect of laundering upon lice (*Pediculus corporis*) and their eggs. Journ. of Parasit., Vol. V, No. 2, pp. 61-68.

[2] Government report on laundry machinery. National Laundry Journ. (Chicago), Vol. 81, No. 1, pp. 4-14.

"5. Run in tumbler fifteen minutes, at a minimum of 140° F.

"We advise live steam (1*a*) or very hot soaking (1*b*) only in cases where there is no heated tumbler (5) available, or where the garments are suspected of being contaminated with very resistant spore-bearing bacteria.

"In other words, we recommend the usual laundry methods for the disinfection and disinsection, because of their added value of cleansing.

"There can be no doubt that the ordinary processes of the laundry will kill all lice and their eggs, and probably all insect life.

"We have proven that woolens can be treated with temperatures which will kill lice and bacteria, without undue shrinkage—that is, 131° F. Washing in *heavy* suds, with motion; 165° F. soaking, without motion; live steam, without motion, except occasionally to remove water of condensation; or dry tumbling of wet garments, do not cause undue shrinkage of woolens."

Dry heat has long been used in destroying lice, such as ironing clothing with hot irons or singeing with a flame, also baking in an oven. The necessary killing temperature for both lice and nits is 60° C. (140° F.) for 20 minutes in case of dry articles. Various types of heat chambers have been devised, but in all cases there should be ample opportunity for fresh heated air to circulate in order to insure equal distribution of heat among the loosely hung garments.

Steam sterilization if available is a satisfactory method of delousing and it is not only disinsecting but also disinfecting. It has some disadvantages as compared with dry heat in that there is some danger from shrinkage, although this we have found to be slight when clothing is properly manipulated, and unless nicely hung up it becomes badly wrinkled and certain stains (blood and excreta) become fixed by steam. Leather, rubber, felt, and books of course must not be subjected to steam sterilization. In the absence of permanent delousing stations at certain army camps the author organized a number of temporary stations by the use of portable sterilizers (known as American Kinyoun-Francis Portable Disinfectors), circular type 40″ in diameter and 96″ long arranged in pairs, side by side, each pair adjacent to a latrine with bath, one being used for blankets and underwear and the other for uniforms. About thirty-five men were handled per load every 30 to 35 minutes and each station was in charge of a commissioned officer and five or six enlisted men as assistants. The following routine directions were in effect:

A. Directions to Men

1. Leave blankets at sterilizer before entering latrine.
2. Undress promptly and assist in determining whether or not you have vermin in your clothing or on your body, or have crab lice or head lice. It is to your interest to get rid of these now.
3. Place your uniform carefully over hangers provided for the same to avoid wrinkling.
4. Empty your pockets completely and do not send leather or rubber goods to the sterilizer.

5. Tie up your underwear, spiral leggins, socks and cap (unless it has leather band) into a bundle with belt, and attach identification disk.
6. Pass under shower and bathe thoroughly, using plenty of soap.
7. Dry with clean towel issued to you.
8. Receive sterilized belongings, dress and leave latrine, receiving blankets at sterilizer.

B. Directions for Sterilizer Unit

1. Follow directions for operation of sterilizer. (See directions posted on sterilizer.)
2. Hang uniforms in carriage carefully so as to avoid wrinkling and do not overcrowd.
3. With load ready, door properly closed, steam up in boiler and pressure in jacket, *produce a vacuum.*
4. Vacuum of from twelve to fifteen inches held for about five minutes. (This is necessary to provide for penetration of steam and is essential to destroy lice if present.)
5. Introduce steam in sterilizer chamber until fifteen to twenty pounds pressure is produced, and *hold* for fifteen minutes.
6. Allow steam to escape and again produce vacuum of about fifteen inches.
7. Break vacuum and unload when zero is reached.
8. Return clothing promptly to men waiting in latrine.

Storage of garments likely to be infested with lice raises the question,—How long will the lice and eggs survive? Since temperature plays an important rôle both in longevity and incubation, it may be said that lice can live without food for ten days at low temperatures (about 40° F.) and for shorter periods at higher temperatures (2 to 3 days at about 85° F.); hatching may be delayed by low temperatures, e.g., Nuttall states 16 days at about 25° C. (77° F.) and the eggs do not hatch at 22° C. (71° F.) or below. It would apparently be safe to assume that dry storage for about 3 weeks would prove effective.

Where it is possible to secure *live steam* its use is strongly recommended in the disinsection of bunk houses, bunks and other accessible structures where delousing operations (also bedbug control) are in progress.

CHAPTER VIII

CONE-NOSES AND BEDBUGS

A. The Cone-Noses

Order Hemiptera, Family Reduviidæ

Order Hemiptera (*Rhynchota*).—The order *Hemiptera* comprises the great order of "bugs," characterized by a jointed, suctorial proboscis which when not in use is commonly folded under the head. The winged members of this order have two pairs of wings and it is on alar characters that the order may be divided into two suborders, viz.: (1) *Heteroptera* in which the first pair of wings (wing covers) is thickened at the base and the distal overlapping portion is membranous, and (2) *Homoptera* in which the wing covers are of about the same thickness throughout.

The *Hemiptera-Heteroptera,* also known as the true bugs, are divided into two divisions, (1) the *gymnocerata* in which the antennæ are conspicuous and capable of being moved freely in front of the head, e.g., *Anasa tristis,* the squash bug, and *Triatoma protracta,* a cone-nose; and (2) the *cryptocerata* in which the antennæ are concealed, situated in small concavities (foveæ) or closely pressed to under side of the head, e.g., *Belostoma griseus* the giant water bug.

The *Hemiptera-Homoptera* have the front of the head, much inflexed, in addition to the characteristic wings already described, as for example, *Cicada septendecim,* the seventeen year locust, and *Eutettix tenella,* the sugar beet leaf hopper. The latter is the carrier of a serious disease of sugar beets known as "curly top."

Family Reduviidæ.—The Reduviidæ belong to the *Hemiptera-Heteroptera,* of which they are typical examples. They are commonly known as kissing bugs, cone-noses and assassin bugs; and are usually predaceous, feeding on the juices of other insects, but many are plant feeders and several species will feed on *mammalian* blood if opportunity is given. Most of them are able to inflict a painful pierce, the proboscis being three jointed and enclosing four hairlike piercing stylets. The head is more or less elongate (cone-nosed), having considerable freedom of motion; the eyes are conspicuous, the ocelli, if present, being located behind the eyes; the sturdy proboscis is capable of being thrust forward, but in repose it lies folded back under the head; the long, slender, four-segmented naked antennæ (basis for the term *gymnocerata*) are located in front of the eyes or the border of the head; the prothorax is strongly developed.

Kissing Bug or Cone-Nose Bites.—No doubt the majority of the cone-nose species do not bite human beings unless carelessly handled. The writer's first experience with a cone-nose was while incautiously plucking a leaf from a tree. The bite was instant and the pain most intense and though the wound was on the finger the pain seemed to extend to the head and was quickly followed by a feeling of faintness. The recovery was but a matter of less than half an hour with no further effects except for a slight local cellulitis.

Reduvius (*Opsicoetes*) *personatus* (Linn.) was apparently unusually abundant during the summer of 1899 and gave rise to much comment as the "kissing bug." Howard [1] quoting Le Conte writes:

> "This species is remarkable for the intense pain caused by its bite. I do not know whether it ever willingly plunges its rostrum into any person, but when caught or unskillfully handled it always stings (pierces). In this case the pain is almost equal to that of the bite of a snake, and the swelling and irritation which result from it will sometimes last for a week. In very weak and irritable constitutions it may even prove fatal."

This species is positively phototropic, hence dashes vigorously at light at night, and often into the face of anyone nearby, biting either face or lips when an attempt is made to remove the insect. It is a coal black species, measuring about two centimeters in length. The prothorax in dorsal aspect has two prominent tubercles or swellings, due to a median, dorsal, longitudinal groove and a transverse posterior groove. It is widely distributed throughout the Eastern United States as far west as the Rocky Mountains and is well-nigh cosmopolitan. The young present a curious masked appearance because of a covering of dust, lint and cast off skins which adheres to the body by means of a sticky secretion. This covering is said to enable these insects to creep upon their prey which consists of other soft bodied insects.

The symptoms produced by the bites of *Triatoma protracta* (Uhler), Fig. 63a, a widely distributed Pacific Coast species, known as the "China bed bug," are described by reporting physicians, viz.: "In a few minutes after a bite the patient develops nausea, flushed face, palpitation of the heart, rapid breathing, rapid pulse, followed by profuse urticaria all over the body. The symptoms vary with individuals in their intensity." Inquiries concerning these insects are most frequent during May and June. It frequently attacks sleeping individuals during the night. It is nearly dead black in color throughout, and averages about 18 mm. in length. The abdomen is broad with a wide margin exposed around the edges of the folded wings lying in the dorsal hollow of the abdomen. Van Duzee reports collecting this species commonly in the nests of wood rats.

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[1] Howard, L. O., 1899. The Insects to which the name "Kissing Bugs" became applied during the summer of 1899. U. S. Dept. of Agric., Div. Ento. Bull. No. 22.

The blood sucking cone-nose or "Mexican bedbug," *Triatoma sanguisuga* Lec., inflicts a very severe bite, which, because of the uniform character of the resulting symptoms, supports the view that a specific venom is injected with the bite. The bite is said to result in "a burning pain, intense itching and much swelling . . . with red blotches and welts all over the body and limbs." The effects of the bite may last for months; however, they usually disappear within a few days. This species is dark brown in color with pinkish segmental markings on the dorsal borders of the abdomen and on the tips of and bases of the hemielytra. They measure from 2 to 2.5 cm. in length. It is probably a typical Mexican species, but is commonly found in the southern United States as far north as Illinois and New Jersey.

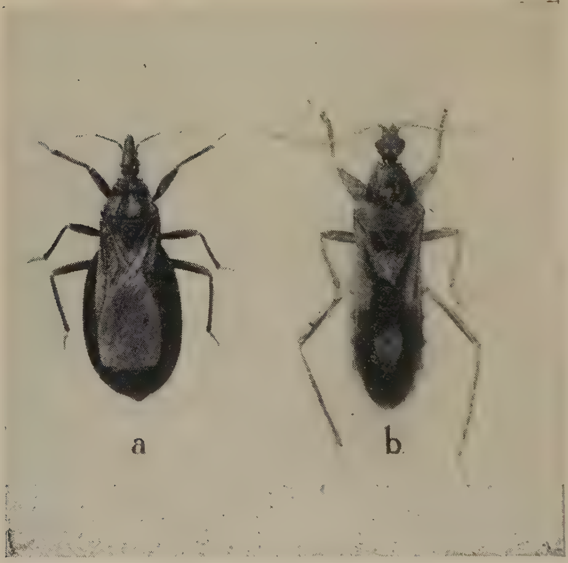

FIG. 63.—Members of the family Reduviidæ. (*a*) *Triatoma protracta;* (*b*) *Rasahus thoracicus.*

The "two spotted corsair," *Rasahus biguttatus* Say and *Rasahus thoracicus* Stal. (Fig. 63b), the former common in the southern states, Cuba and South America, and giving way to the latter in the Northwest and California, is the subject of many complaints. Howard (1899, *loc. cit.*) cites the following paper concerning "so-called Spider Bites" by Dr. A. Davidson in the Therapeutic Gazette of February 15, 1897, viz.:

"He arrives at the conclusion that almost all of the so-called spider bites met with in Southern California are produced by no spider at all but by the *Rasahus biguttatus* (*thoracicus*). The symptoms which he describes are as follows: Next day the injured part shows a local cellulitis with a dark central spot; around this spot there frequently appears a bulbous vesicle about the size of a ten-cent piece and filled with a dark grumous fluid; a smaller ulcer forms underneath the vesicle, the necrotic area being generally limited to the central part, while the surrounding tissues are more or less swollen and somewhat painful. In a few days with rest and proper care the swelling subsides, and in a week all traces of the cellulitis are usually gone. On some of the cases no vesicle forms at the point of injury, the formation probably depending on the constitutional vitality of the individual or the amount of poison introduced."

A description of the blood sucking habits and effect of bite of *Rhodnius prolixus* Stal., the "Chinchorro" of Cuba, is given by Bruner,[1] viz.:

> "(1) El 'Chinchorro' (*Rhodnius prolixus* Stal.), ataca al hombre para chuparle la sangre, que evidentemente le puede servir de alimento. Después de estar muy hinchado por la sangre ingerida, el ejemplar ensayado gradualmente asumía su forma normal, indicando que había digerido ésta. (2) El insecto no pica a uno defensa propia, pues tratamos de todas maneras el conseguir que lo hiciera, pero sin resultados. Solamente pica cuando su apetito lo requiere y cuando está tranquilo. En este respecto difiere de varias de las otras especies de su familia (*Reduviidæ*), los cuales pican a uno al ser cogidos en la mano, produciendo heridas dolorasas. (3) La picada del 'chinchorro' no es peligrosa al hombre, aunque puede causar hinchazón e inflamación más o menos estendida, ascompañada por una ligera picazón. (La posibilidad de que pueda actuar como transmisor de enfermedades infecciosas de la sangre entre personas enfermas y sanas que vivan en proximidad, no debe olvidarse.) (4) El efecto de la picada varía según la persona atacada y mientras uno muestra resistencia completa, otra puede sufrir considerables inconveniencias. Parece verter en la herida un veneno poco activo, el cual causa la inflamación o hinchazón. (5) La picada no produce dolor ni sensación alguna a la persona en el momento, de modo que no se da cuenta del ataque; una inflamación, hinchazón y ligera picazón empieza después de un medio día, aproximadamente, y puede continuar de 2 a 5 días."[2]

Treatment for the bite of cone-noses has a twofold object; first to neutralize the specific poison injected by the insect, and second also to prevent extra infection which is liable to occur because of the indiscriminate feeding habits of the insect. Bathing the wound with corrosive sublimate in proportions of 1 to 1000 is said to give good results and the pain may be somewhat relieved by the application of ammonia. The use of potassium permanganate as recommended for spider bite is also suggested.

Life History.—The life history of but few species of *Reduviidæ* has been worked out completely and that mainly in the genus *Triatoma* representing a typically hæmatophagous group, i.e., feeding either directly on a warm blooded host or taking blood "second hand" from such blood-suckers as bedbugs. *Triatoma protracta* deposits large whitish eggs (Fig. 64), in small numbers (3 to 6) at a laying under laboratory conditions in almost any sort of vial or container in which the female may happen to be imprisoned. The eggs are deposited during midsummer and late summer at least until early September in Berkeley (California) indoors. Hussey[1] reporting the observations of Neiva of Rio de Janeiro, states that oviposition begins within 30 days after mating and that a female lays from 160 to 220 eggs in masses containing from one to 45. Hoffman[2] reports about 600 eggs from one female *Triatoma flavida* Neiva. The eggs hatch in from 8 to 16 days. Under cooler climatic conditions (Berkeley) we have found that *T. protracta* eggs usually require an incubation period of between 2 and 3 weeks, the first molt taking place in 7 to 8 days after hatching, the first larval feeding having taken place in from 2 to 5 days after hatching. The larvæ are wingless and usually feed on soft bodied insects, but if given the opportunity may suck blood from warm blooded animals very early. The length of the life cycle of *Triatoma rubrofasciata* was found by Neiva to require 210 days and for *T. megista* 260 days, which evidently indicates that as for *T. protracta* there is but one generation a year.

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[1] Bruner, Stephen C., 1922. Sobre el "Chinchorro" (*Rhodnius prolixus*). Revista de Agricultura, Comercio Y Trabajo, Vol. 5, No. 2 (April, 1922), pp. 13-16.

[2] That this species is probably *Triatoma flavida* Neiva and not *Rhodnius prolixus* Stal. is suggested in a paper by Dr. W. H. Hoffman published in Entomological News, April 23, 1923.

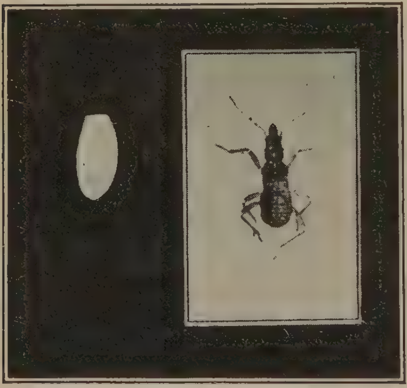

FIG. 64.—Egg (left) and larva (right) of a cone-nose, *Triatoma protracta*. × 4.4.

Chagas Disease (Brazilian Trypanosomiasis). — In 1909 Chagas[3] reported from Brazil on endemic human trypanosomiasis prevalent among very young children and causing a high mortality. The acute disease is marked by a high fever lasting often several weeks, and an enlargement of the lymphatics and especially the thyroid, whence the term "parasitic thyroiditis." In its chronic form, the disease is commonly manifested by such symptoms as imperfections of the heart, motor paralysis, mental weakness, idiocy and infantilism.

The causative organism is *Trypanosoma* (*Schizotrypanum*) *cruzi* Chagas which occurs in the blood during the acute stage of the disease and later in various tissues such as the heart, glandular tissue, and nervous system where the *trypanosomes* multiply. The intermediary host is the cone-nose *Triatoma megista* (Burm.), known to the natives as the "barbeiro," which is commonly found in native huts and is a fierce blood-sucker. Chagas found that the trypanosomes changed to round bodies (Leishmania-like) in a few hours after the bug fed on infectious blood and that a series of developmental changes occur giving rise to infectious forms in about 8 days, infection probably taking place by the bite of the bug. The incubation period in the human is said to vary from 10 to 14 days after the insect attack. The bug is believed to remain infective literally for months, probably for the rest of its life as in certain other insect disease vectors.

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[1] Hussey, R. F., 1922. A bibliographical notice on the Reduviid genus *Triatoma*. Psyche, Vol. XXIX, No. 3, pp. 109-123.

[2] Hoffman, W. H., 1923. Observations on the occurrence and biology of *Triatoma flavida* in Cuba. Entomological News, Vol. 34, No. 4, pp. 111-113.

[3] Chagas, C., 1909. Ueber eine neue Trypanosomiasis des Menschen. Memorias do Instituto Oswaldo Cruz, I, pp. 159-218.

While Chagas believes the infection to be introduced by the bite of the bug, Brumpt[1] states that infection results through the infective dejecta of the insect being deposited upon the skin of the host when the insect bites and inoculation resulting through the mucous membrane of the mouth, inasmuch as the cone-nose usually bites the face and lips of sleeping persons. It is based on experiments with another vector, *Rhodnius prolixus* Stal., that Brumpt came to hold the above opinion; this bug defecates immediately after it has withdrawn its proboscis, which is said not to be the case with any of the *Triatoma* species. Inoculation would then result through scratching or rubbing the infective feces into an excoriated skin.

Preventive Measures.—Since these insects are all quite large, considerable protection is afforded through the use of window and door screens and sleeping under bed nets. Caution should be exercised when one of these bugs alights on the face or hand; do not grasp it between the fingers, but give a quick snap and crush it when it falls to the ground. They are very rapid in their movements. When it is known that the bugs are about it is a good policy to search the beds and bedrooms carefully.

Since it is known that the causative trypanosomes are harbored in nature in the common Brazilian armadillo and various species of rodents, another means of control is open; namely extermination of these reservoirs.

B. The Bedbugs

Order Hemiptera, Family Cimicidæ

Cimicidæ.—The family Cimicidæ (Acanthiidæ) comprises the well-known bedbugs, characterized by their very short, broad head, broadly attached to the prothorax, well developed compound eyes, ocelli absent, antennæ four-jointed, the jointed proboscis enclosing four hair-like stylets lying in a groove beneath the head and thorax, very short pad-like elytra, amounting to a practically wingless condition of the bug. The bodies are broad and flat, enabling the bugs to creep into narrow crevices. A nasty pungent odor is attached to the group as a whole with few exceptions. They are night prowling and blood-sucking in habit, some feeding on birds and bats and others on human beings.

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[1] Brumpt, E., 1913. Immunite partielle dans les infections a *Trypanosoma cruzi* transmission de ce trypanosome par *Cimex rotundatus*. Rôle régulateur des hôtes intermédiaries. Passage à travers le peau. Bull. Soc. Path. Exot., Vol. VI, No. 3, pp. 172-176. (Abstract in the Review of Applied Ento., Ser. B, Vol. 1, No. 7.)

The three principal genera of the family Cimicidæ [1] are: (1) Cimex, in which the rostrum is short, reaching about to the anterior coxæ, antennæ four-jointed, the apical joints slender, prothorax semilunar in shape, anterior tibiæ more than twice as long, and the posterior three times as long, as the tarsi, which are three jointed, e.g., *Cimex lectularius* L. the cosmopolitan bedbug, *C. hemipterus* Fabr. (= *C. rotundatus* Sign.) tropical and subtropical, also known as the Indian bedbug, *C. boueti* Brumpt,[2] the tropical bedbug of Africa and South America, all of which resemble each other very closely as do the following: *Cimex pipistrelli* Jenyns, parasitic on bats in Europe and *C. pilosellus* Horv. on bats in America; (2) Œciacus, in which the body is clothed with long silky hairs, the third and fourth joints of the antennæ only a little thinner than the first and second and filiform, e.g., *Œciacus hirundinus* Jenyns, the European barn-swallow bug and *O. vicarius* Horv. the corresponding American species; (3) Hæmatosiphon, in which the rostrum is long, reaching to the posterior coxæ, of which *Hæmatosiphon inodorus* Duges is the only known species. This species infests poultry in the southwestern United States and Mexico and is often a serious household pest.

The Common Bedbug.—The common adult bedbug, *Cimex lectularius* Linn. (Fig. 65), measures from 4 to 5 mm. in length, 3 mm. in breadth, is obovate in form and much flattened. The adult is reddish brown in color, though the young insects are yellowish white. Among the local names applied to these insects are "chinches," "chintzes," "red coats," "mahogany flats," "wall louse," "bedbugs," or simply "bugs."

Bedbugs, like the lice, have been the constant companions of man for centuries,—the earliest writings on Natural History (Pliny and Aristotle) make mention of them.

Habits and Life History.—Bedbugs are nocturnal in their feeding habits, hiding in crevices during the day. At night they are very active, crawling out of their hiding places often to travel considerable distances to attack their victims. This is especially true where iron bedsteads are used which do not provide convenient hiding places for the bugs. Ordinarily where the old-fashioned wooden bedsteads are used the bugs stay closer to their point of attack. They are gregarious, hence often great assemblages may be found in some convenient crevice. In such situations the eggs are usually deposited.

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[1] Horvath, G., 1912. Revision of the American Cimicidæ. Annales Musei Nationalis Hungarici, Vol. X, pp. 257-262.

[2] Joyeux, Charles, 1913. Biologie de *Cimex boueti.* Arch. de Parasit. T. XVI, pp. 140-146.

The females deposit from 75 to 200 rather large yellowish white eggs easily visible to the naked eye. As in many Hemiptera, often only very few eggs are deposited at a time and oviposition occurs at intervals during a period of from two to three months. The period of oviposition is apparently limited to the spring and summer months, notwithstanding the fact that the insects are commonly favored by warm rooms during the winter. The eggs are whitish in color and distinctly reticulated. The young, which have the general form of the adults (therefore simple in their metamorphosis), hatch in from 5 to 12 days, according to temperature, which also affects their later growth. Thus the results of experiments and observations of writers differ greatly with regard to the life history. The time required for development from the egg to maturity is given at from 45 days to 11 months and there may be two or more generations. Ordinarily 8 to 10 weeks are required to reach maturity. The presence or absence of food influences this period greatly. Marlatt[1] has shown that bedbugs molt five times and that the minute wing pads make their appear-

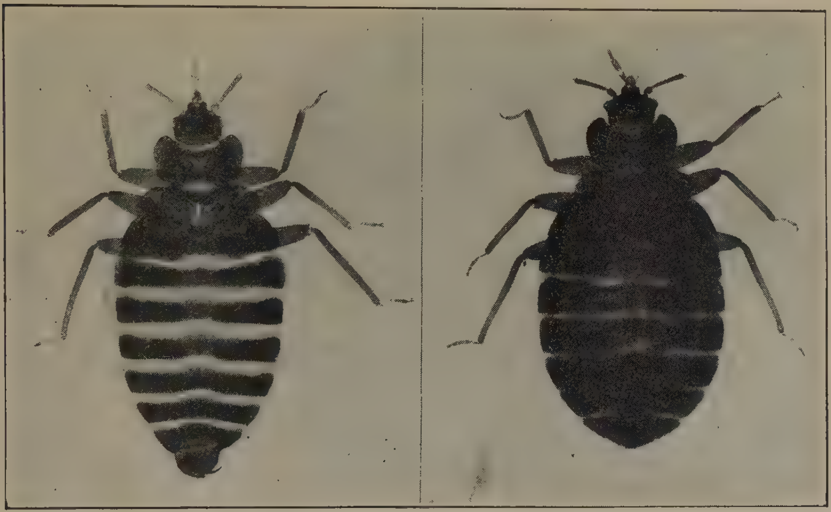

FIG. 65.—The common bedbug, *Cimex lectularius.* Male, left; female, right. Also shows piercing stylets exposed. × 10.

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[1] Marlatt, C. L., 1902. The Bedbug. Circ. No. 47, Second Series, U. S. Dept. of Agric., Div. of Entomology.

ance with the last molt. He also found that ordinarily but one meal is taken between each molt and one before egg deposition and that an average period of 8 days is required between moltings.

Methods of Distribution.—Bedbugs, like lice or any other organism, cannot originate spontaneously in filth as is believed by many; they must be introduced in some manner, either in the form of eggs, young or adults. Thus the introduction of one impregnated female might furnish the nucleus for a well-developed colony in a few months. Hence the best regulated household is not exempt from invasion, though cleanliness is the best preventive against the multiplication of any household pest.

Public conveyances are commonly means for the dissemination of bedbugs. As Smith[1] has well said, "I have seen them in railroad cars, trolleys, boats, omnibuses and carriages, and have noted them crawling on the clothing of well-dressed fellow passengers who probably did not bring them in." Furthermore, migration from house to house by way of water pipes, walls and the like is not at all unlikely when infested houses are vacated and the food supply is cut off. They are also easily carried in clothing, traveling bags, suit cases, etc.

Bedbug Bites.—Persons "bitten" by bedbugs are differently affected; in some the bite produces marked swellings and considerable irritation, while in others not the slightest inconvenience is caused. (The same condition is found in the case of flea bites and mosquito bites.) The bite, so-called, of the bedbug is produced by puncturing organs of the Hemipteron type already described. It is probable that the pierce of these stylets, unattended by contamination or specific poisons, would produce little pain. The local irritation is unquestionably produced by a specific poison secreted by the salivary glands and introduced in the act of feeding.

The fact that the bedbug is obliged to feed at least five different times either upon the same or a different host,—the latter being the case most probably in rooming houses, hotels and crowded dwellings,—leads to the question of disease transmission.

Disease Transmission.—In consequence of statements made by a number of authors that the bedbug is capable of transmitting plague and other septicemic infections, Nuttall[2] carried on a series of experiments with these insects. Mice were used in these experiments because they are very susceptible to the affections in question. He allowed the bugs to bite mice which had just died or were dying of anthrax, plague and mouse-septicemia and then transferred them to healthy mice. Nuttall's experiments with anthrax are particularly instructive. Mice inoculated with anthrax died in from 18 to 24 hours, after which they were placed in glass-covered dishes and hungry bugs introduced. As soon as the bugs had sucked a little blood they were removed to test tubes by means of a small camel's hair brush and transferred to a shaved spot on healthy mice, by inverting the tubes. Eight mice bitten by 124 infected bugs all remained healthy. Variations of this experiment gave similar results. It was found that the anthrax bacilli die in the stomach of the insect in 48 to 96 hours at 13° to 17° C. and in 24 to 48 hours at 37° C., and that the feces from the bugs contained living bacilli during the first 24 hours after feeding. In view of these experiments it may be concluded that infection through the bite of a bedbug either does not occur or is exceptional. That infection might occur if recently infected bugs were crushed while feeding and the punctured parts scratched is to be expected.

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[1] Smith, John B., 1909. Our Insect Friends and Enemies. J. B. Lippincott Co., 314 pp.

[2] Nuttall, 1899. *Loc. cit.*

Kala Azar.—Kala azar or dumdum fever is a highly fatal protozoal disease of India, having in many respects some similarity to malignant ague, but does not respond to quinine. The causative organism, *Leishmania donovani* (Ross), is found in closely packed masses in the cells of the spleen and other viscera. These organisms, also known as *Leishman-Donovan* bodies, are said to be a non-flagellate stage which develops a flagellate stage in some other host. They are "approximately circular or oval, 2.5 to 3.5 micra in diameter, clearly outlined, and appear to possess a distinct cuticle, as they retain their shape and are rarely seen distorted in films. The two chromatin masses are characteristic, the large one staining slightly and the small one intensely with Romanowsky. The masses are usually situate opposite each other in the short axis of the parasite."

Observations made by Patton[1] show that flagellate forms develop in from 5 to 8 days in bedbugs after feeding on kala-azar patients. Much circumstantial evidence strongly implicates both the Indian bedbug, *Cimex hemipterus* Fabr. (= *C. rotundatus* Sign.) and our common bedbug, *Cimex lectularius* Linn. as probable important transmitters of this disease.

Relapsing Fever (Spirochætosis).—The relapsing fevers traceable to *Spirochæta duttoni* and *Spirochæta recurrentis* are probably disseminated to some extent by the bedbug (*Cimex lectularius*), since it has been shown by Nuttall[2] that the spirochætes survive in the bodies of bugs for a period of 6 days at a temperature of 12° C., and a much shorter period (6 hours) at 20° to 24° C. He, however, succeeded in transmitting the disease to a mouse, in only one instance, by transferring thirty-five bugs from an infected mouse to an uninfected mouse. The evidence at hand seems to indicate that the bedbug is relatively unimportant.

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[1] Patton, W. S., 1907. Scient. Mem. of the Gov. of India, Nos. 27 and 31.

[2] Nuttall, G. H. F., 1913. The Herter Lectures. I. Spirochætosis. Parasitology, Vol. 5, No. 4, pp. 262-274.

Control.—The habits of these parasites indicate in a measure the methods useful in their eradication in a given situation. The ease with which they secrete themselves in very narrow crevices provides safety against anything but very penetrating materials. Thus pyrethrum powder is only useful where the insects are quite exposed or within reach of a blower. The newer metal bedsteads are easily kept free from the bugs, while the old-fashioned wooden bedsteads are more difficult to handle; however, the writer has seen some very bad infestations entirely eliminated by the use of kerosene applied by means of a tail feather from a fowl.

A thorough infestation of bedbugs will require a more strenuous campaign. Where the infestation has reached such proportions as to include several rooms or even an entire building, the more rapid and effective fumigation methods are far preferable, requiring less labor and producing better results.

Hydrocyanic acid gas is perhaps the most effective of fumigating agents, but the greatest care must be exercised in its use since the gas is deadly to all forms of animal life and extremely penetrating. Rooms above apartments in which this gas is being applied should not be occupied during or immediately after the process. Sparrows have been known to drop from the eaves of houses in which cyanid fumigation was going on. However, with proper precautions very little danger is involved.

To prepare a room for cyanid fumigation, all wet or moist foodstuffs must be removed (dry materials such as flour, meal, bread, etc., need not be removed); if the house is occupied, *there must be no crevices leading from the room to be fumigated to occupied rooms.* It is best that the house should be vacated during the process,—this need be for only a period of 5 or 6 hours. Fumigation should not be undertaken when it is cold; a temperature of about 70° F. gives best results. If there is a fireplace in the room, this should be covered with a blanket or other covering. All crevices, such as occur around the doors and window sashes, keyholes, etc., must be tightly covered with strips of paper pasted in place with a very dilute flour paste, or as some have found, merely soaked in water. The cubic contents of the room must be estimated and sufficient ingredients provided to do the work. One ounce of potassium cyanid for every one hundred cubic feet of space is necessary. To generate the gas sulphuric acid and water must be used. The following proportions are needed for 100 cubic feet of space:

Potassium cyanid (98%)	1 oz.
Sulphuric acid (about 66° Beaumé)	1 fluid oz.
Water	3 fluid oz.

or for 130 cubic feet of space:

Sodium cyanide (129%)	1 oz.
Sulphuric acid	1 fluid oz.
Water	2 fluid oz.

To proceed place the water (in proper proportion) in a heavy two to three gallon earthen jar placed on thick folds of paper to catch spattered liquid, then slowly add the sulphuric acid (water always first, then the acid), lastly drop a paper bag containing the cyanid into the liquid, holding same at arm's length, and *immediately* beat a hasty retreat, carefully closing the door. In treating buildings with more than one floor the operator must always begin at the top and work downward. After the expiration of about 5 hours, open the windows from the outside and permit the room to "air" until the "peach kernel" odor has disappeared. The contents of the jar should be carefully disposed of.

To fumigate with sulphur, a very efficient method to destroy bedbugs and other vermin, the rooms are prepared as for hydrocyanic acid gas fumigation. All metal objects and fine, vegetable dyed fabrics must be removed, if possible; metallic objects should also be covered or, what is better, coated with vaselin. Sulphur, at the rate of 4 pounds to every 1,000 cubic feet of space, is placed in a shallow iron pot or skillet which is placed on bricks or stones in a tub in which there is a little water in order to prevent spilling out and igniting the floor. The sulphur is easily ignited by pouring over it a few ounces of wood alcohol (or grain alcohol) and then lighting it with a match. Fumigation must continue for at least 2 hours, when the doors and windows should be opened to ventilate the room before occupancy.

While sulphur fumes are extremely useful against insects and other animal life, such as rats and mice, the liability to bleach fabrics and tinted paper and tarnish metals must be taken into consideration.

Corrosive sublimate (1 to 500 solution) applied to bedsteads, floors, and other hiding places is efficient. The corrosive sublimate preparation should be applied with a mop. In case it is necessary to apply by hand, rubber gloves should be worn to protect the skin. For mattresses, bedding and like materials, no treatment is superior to steam sterilization where the necessary facilities are at hand. By use of this medium, death to all stages is accomplished in a few moments if the steam has direct access to the insects. Where large bundles or piles of mattresses are placed in a steam sterilization chamber it is necessary to produce a partial vacuum followed by 15 to 20 minutes exposure to steam at 20 pounds pressure. Applying live steam by means of a suitable hose to bunks and crevices of bedbug-infested bunk houses is very effective.

Infested bedsteads that can be "taken down" may be dipped in vats of corrosive sublimate solution, or if metal, fine results are obtained by heating all parts with a plumber's blow torch until the paint starts to blister, care being taken not to overlook the springs at the time of treatment.

Where it is possible to heat the infested apartments to 130° F., as in the case of buildings equipped with a heating plant, the maintaining of this temperature for 2 to 3 hours gives good results.

The natural enemies of the bedbug, such as red ants and cockroaches, do not enter in as practical factors, inasmuch as they are just as undesirable as the bedbug itself.

CHAPTER IX

MOSQUITOES

Order Diptera, Family Culicidæ

General Characteristics.—As members of the Order Diptera, mosquitoes partake of the general characters of the order; namely, reduction of the metathoracic (posterior) pair of wings, in place of which there occurs a pair of tiny knobbed organs known as the halteres or balancers, most distinctly visible in the crane flies (Tipulidæ) (Fig. 66). The Diptera are commonly divided into two suborders: (1) Nematocera, in which the antennæ are many-jointed and filamentous, as in the mosquitoes (Culicidæ), crane flies (Tipulidæ), midges (Chironomidæ) and buffalo gnats (Simuliidæ); (2) the Brachycera, in which the antennæ

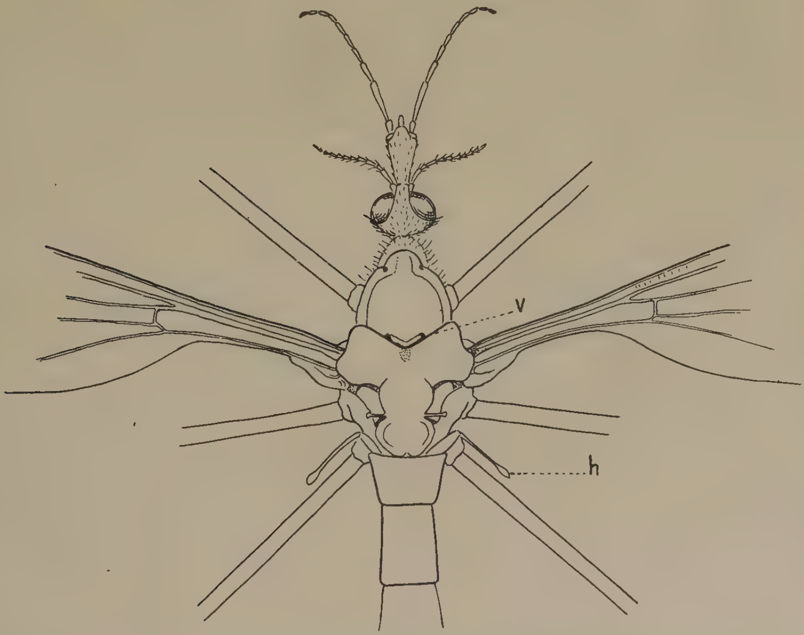

FIG. 66.—Head and thorax of a crane fly (Tipulidæ), showing appendages, halteres (*h*) and characteristic v-shaped suture on thorax (*v*).

are short and not filamentous, as in the horseflies (Tabanidæ), house flies (Muscidæ) and botflies (Œstridæ).

The Culicidæ (mosquitoes) are distinguished from all other Nematoceran Diptera by (1) the character of the wing venation (Fig. 67), which varies somewhat within the family; (2) by the presence of characteristic scales clothing the wings, and more or less abundant on the body and head (Fig. 68). The family may be divided into two divisions; the Corethrinæ or short-beaked, generally non-blood-sucking forms represented by the genus Corethra (Fig. 69), the larvæ of which are almost transparent and are known as "phantom larvæ," and the Culicinæ or long-beaked, blood-sucking, true mosquitoes. The males of all mosquitoes are non-blood-sucking and have plumose antennæ.

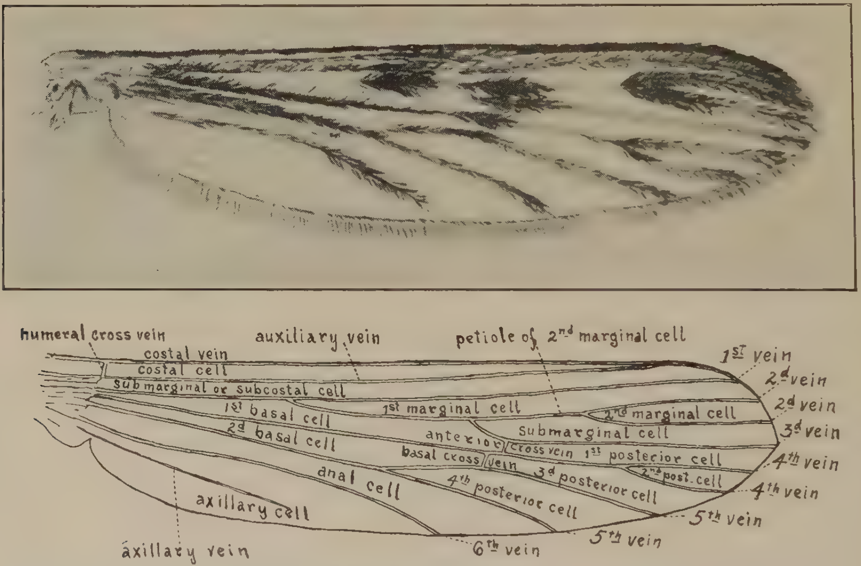

FIG. 67.—Showing (upper figure) scaly wing of a mosquito with spots of Anopheles; (lower figure) wing venation of a mosquito with veins and cells named and numbered for systematic purposes. × 23.

Nearest Allies.—There are many Dipterous insects which may be easily mistaken for mosquitoes unless a careful examination is made. For all practical purposes the characteristics referred to above should serve to determine whether the insect in hand is a mosquito or not. It is true that other families of Diptera are in some cases provided with scales, but other simple characters to be pointed out later should serve to eliminate these. Insects most commonly mistaken for mosquitoes are members of the family Chironomidæ, the midges. According to Williston, these may be distinguished from mosquitoes in that the costal vein is not continuous on the posterior side of the wing. The wings are usually bare or in some may be hairy. The proboscis is short, and in all except the "punkies" or "no-see-ums" are non-blood-sucking (Ceratopogon, Culicoides, Tersesthes, and other genera). The most common Chironomids (Fig. 70) which often occur in enormous swarms over or near swamps have bare wings, plumose antennæ and do not bite. In size and general form they resemble mosquitoes very closely, particularly male mosquitoes. Many species of the Chironomidæ have blood-red larvæ known as "blood worms."

Members of the family Tipulidæ, crane flies or "daddy long-legs," are also frequently mistaken for mosquitoes. The commoner species are easily distinguished by the presence of a V-shaped suture situated dorsally on the thorax (mesonotum) (Fig. 66) and by the blunt, non-piercing mouth parts. The wings are usually devoid of scales or hairs (some exceptions). Other mosquito-like Diptera are the Dixa midges (Fam. Dixidæ), in which the mouth parts are blunt and the wing veins are devoid of scales; members of the family Psychodidæ, moth-like flies, also known as "owl midges" (Fig. 91), have the body and wings densely clothed with hairs and are not so easily mistaken for mosquitoes.

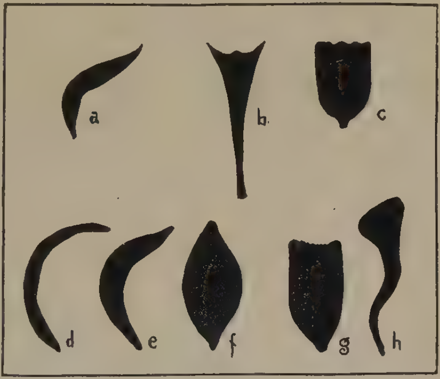

Fig. 68.—Varieties of Culicid scales. *a, b, c,* head scales, (*a*) narrow curved, (*b*) upright forked, (*c*) flat; *d-h,* thoracic scales. (Redrawn after Stephens and Christophers.)

Classification of Mosquitoes.—Although most authors have discarded the relative length of palpi as a reliable character in separating the Culicinæ into two or more divisions, we still find this very practical as a means of identification particularly in localities where malaria-mosquito control work is in progress. On this basis the anophelines can be crudely distinguished from all other mosquitoes, i.e., the palpi of the female are nearly or quite as long as the proboscis (Fig. 71).

The determination of the genera and species by some authors is based quite largely on the character of the scales on the head and body. These are of several varieties, as shown in Fig. 68. The occurrence and arrangement of these scales on the head, thorax, abdomen, and wings provided a basis for some of Theobald's work, now looked upon as obsolete. However, the following statement by Stephens and Christophers illustrates the scheme, "all mosquitoes belonging to the genus Culex have on the head (1) narrow curved and (2) upright forked, but only (3) a few flat scales laterally; whereas all mosquitoes belonging to the genus Stegomyia [Aëdes *pro parte*] have on the head (1) no narrow curved scales, (2) a few upright forked and (3) flat scales, covering the whole of the head." In Anopheles there are "upright forked scales only on the head" (Fig. 72).

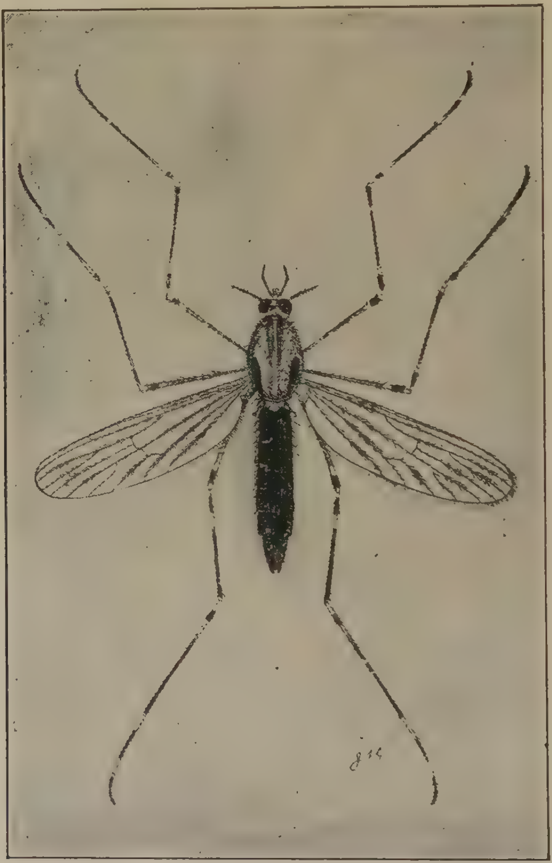

FIG. 69.—Corethra, easily mistaken for a mosquito, is an insect belonging to the family Culicidæ (note scaly wings) but is non-blood-sucking. (After Smith.) × 12.

The *ungues* or tarsal claws have been made use of by some authors as crude characters in classification. In some species the claws are not toothed (simple) and in others they are toothed. Wing venation has also served as a basis for classification. The student will also find Figs. 73, 74 and 75 useful in work of this nature.

Classification based on hypopygia.—The difficulties encountered in undertaking a classification of mosquitoes based on the male genitalia

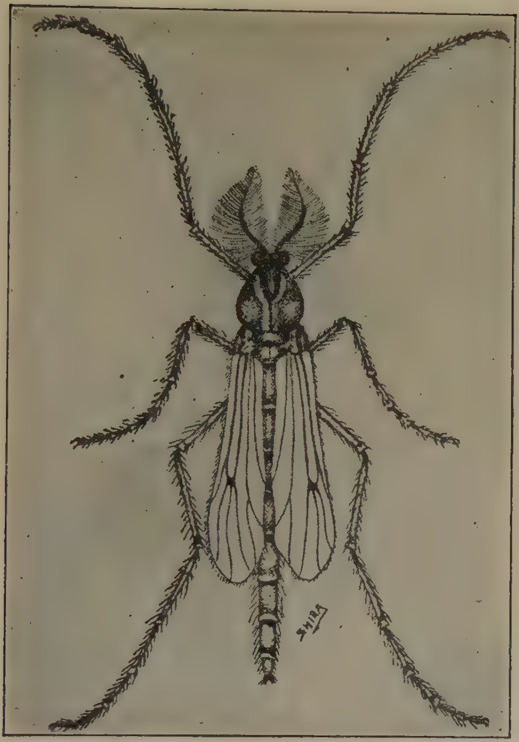

FIG. 70.—A midge (Chironomidæ), easily mistaken for a mosquito. (After Osborn.) × 12.

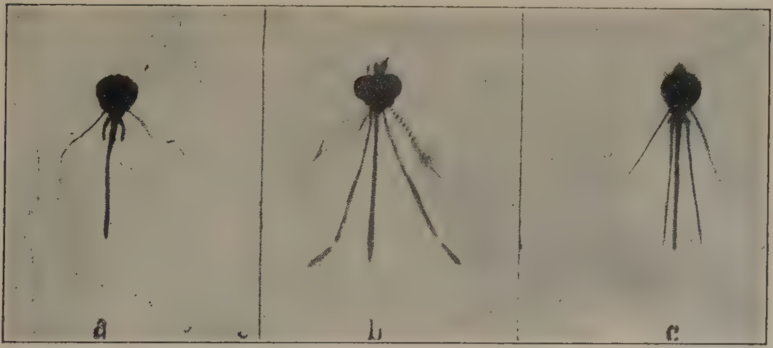

FIG. 71.—Heads of mosquitoes, showing relative length of palpi. Useful in distinguishing the two main subdivisions of mosquitoes. *a*. Culicine; *b*. male of either group; *c*. Anopheline.

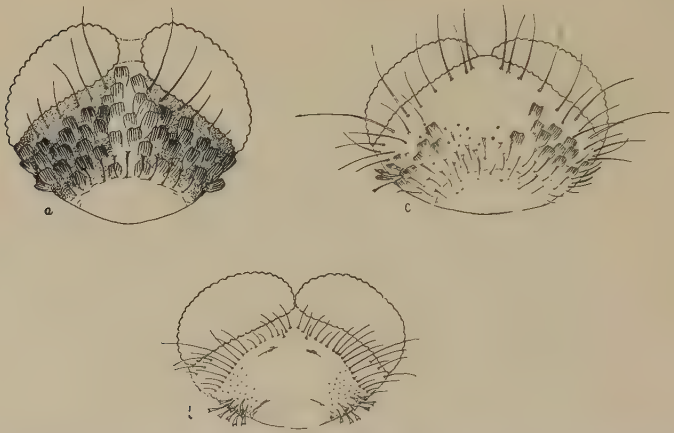

FIG. 72.—Occurrence and arrangement of scales on the heads of mosquitoes. (*a*) Stegomyia; (*b*) Anopheles; (*c*) Culex. (Redrawn in part after, Stephens and Christophers.)

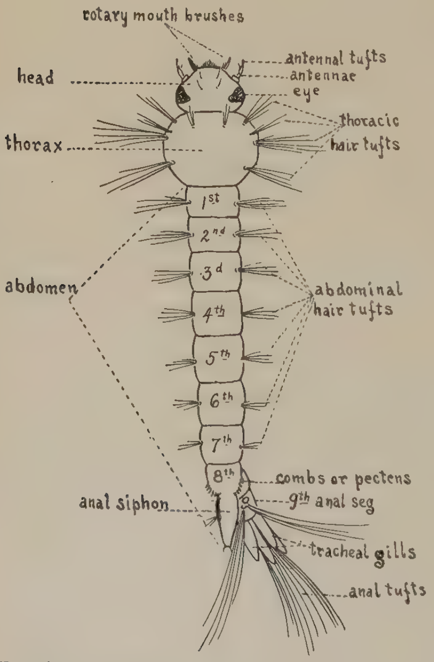

FIG. 73.—A mosquito larva with parts used in classification named. (Adapted after J. B. Smith.)

or more accurately the male hypopygium are (1) the necessity of macerating the specimen and mounting for microscopic study, and (2) the confusion of names applied to the various parts by different writers which makes it difficult to apply the published keys.

The male hypopygium of mosquitoes is made up of four separate groups of structures: (1) the chitinous ring formed by the ninth abdominal segment, (2) the appendages of this segment, (3) the tenth abdominal segment surrounding the anus, and (4) the chitinization of the genital tube itself.

Christophers has shown that after the emergence of the male mosquito a torsion of 180° takes place at the union of the seventh and eighth segment, the tergites of the eighth to tenth segments becoming ventral and the sternites dorsal. For this reason the terms dorsal and ventral as applied to these segments are abandoned as confusing and the terms upper and lower are employed to express their position after the torsion has taken place. The following explanation of the nomenclature (Fig. 76) used in this system of classification is based on a criticism of the various terms applied to the various parts by Edwards[1] (1920) and due regard is given to both priority and fitness and the table (Table II) is patterned after one given by the same author.

1. The ninth segment is present as a narrow strip of chitin representing the sternite, and a wider strip, the tergite, which bears two lobes, *the lobes of the ninth tergite.* The lobes are practically indistinguishable in Anopheles, but prominent in Aëdes and having stout spines, while in Culex, although prominent, the bristles are replaced by hair-like spines.

2. Attached to the ninth sternite are two stout pincer-like appendages that stand out as the most prominent part of the hypopygium. These hollow, chitinized tubes are the *side pieces* and bear terminally a second joint known as the *clasper* which in turn generally has a *claw* terminally or sub-terminally. In most genera the tube of the side piece is complete but in Aëdes a membranous hollow occurs on the inner side, thus producing an *upper* and *lower* flap of chitin. The lower flap bears two protuberances, one at the apical and one at the proximal end of the hollow. These are known respectively as the *apical* and *basal lobes.* In some genera (Aëdes, Anopheles) there originates on the upper flap of the side piece an elongate appendage known as the *claspette.* Also attached to the side pieces as a continuation of the lower side and articulating within the ninth segment with the *basal plate* of the genital tube is the *apodeme.*

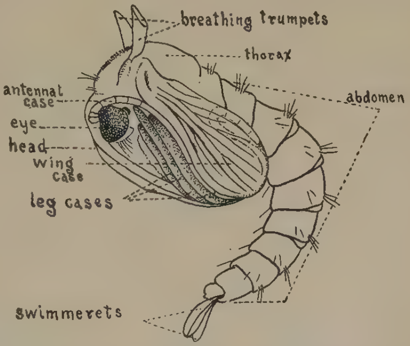

FIG. 74.—A mosquito pupa with parts used in classification named. (Adapted after J. B. Smith.)

3. The tenth or anal segment is almost entirely membranous in Anopheles but in some of the other genera the sternites are produced into two elongate projections, sometimes bearing rosettes of heavy bristles or teeth.

4. The genital chitinizations which occur between the ninth and tenth sternites are spoken of collectively as the *œdoeagus.* The *basal plates* are chitinized structures which connect the main portion of the genital tube with the apodemes of the side pieces. At their distal ends they are connected with the heavily chitinized, out-curving appendages known as *parameres.* Enclosed by the parameres are ornately lobed paired structures surrounding the opening of the genital tube known as the *mesosome.* In Anopheles the entire *aedoeagus* is restricted to a tubular column sometimes bearing pointed leaf-like rays at its tip. (Fig. 76.)

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[1] Edwards, F. W., 1920. The nomenclature of the parts of the male Hypopygium of Diptera Nematocera, with special reference to Mosquitoes. Annals Trop. Med. and Para., Vol. XIV, No. 1, pp. 23-40.

TABLE II

SYNONOMY OF HYPOPYGIAL PARTS OF MALE MOSQUITOES[1]

TERMS ADOPTED (AFTER EDWARDS 1920)	TERMS USED BY FELT 1905	TERMS USED BY HOWARD DYAR & KNAB (MONOGRAPH OF MOSQUITOES)	TERMS USED BY DYAR 1918
Lobes of ninth tergite	Setaceous lobes	Basal appendages	Basal appendages
Ninth Sternite	....	....	....
Side Piece	Basal joint of clasp	Side Piece	Side Piece
Apical lobes	Claspette	Apical lobes (subapical lobes)	Apical lobes
Basal lobes	Claspette	Basal lobes (subbasal lobes)	Basal lobes
Claspettes	Harpes	Harpagones	Harpagones
Apodeme	....	....	....
Clasper	Second joint of clasp	Clasp filament	Clasp filament
Tenth Tergite	....	....	....
Tenth Sternite	Harpes (Culex) harpagones (Aëdes)	Harpes	Harpes
Aedoeagus	Unci	Unci (harpagones in Culex in part)	Unci
Basal plate	....	....	Ligament
Parameres	....	Plate of harpagones (Culex)	First uncal plate (Culex)
Mesosome	Harpagones (Culex)	Unci; Branches of harpagones in Culex in part	Second to fourth uncal plates (Culex); Unci

KEY TO CULICID GENERA OF THE UNITED STATES

Postnotum[2] with setæ—Tribe *Sabethini*
Genus *Wyeomyia* Theob.
Postnotum without setæ—Tribe *Culicini*

1. Wing membrane without microtrichia—*Uranotaenia* Lynch—Arribálzaga
Wing membrane with microtrichia—2
2. Proboscis rigid, curved—*Megarhinus* R.-D.
Proboscis normal—3
3. Scutellum[2] rounded, without lobes—*Anopheles* Meig
Scutellum trilobed—4

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[1] Prepared by S. B. Freeborn.
[2] For position of metanotum and scutellum see Fig. 81.

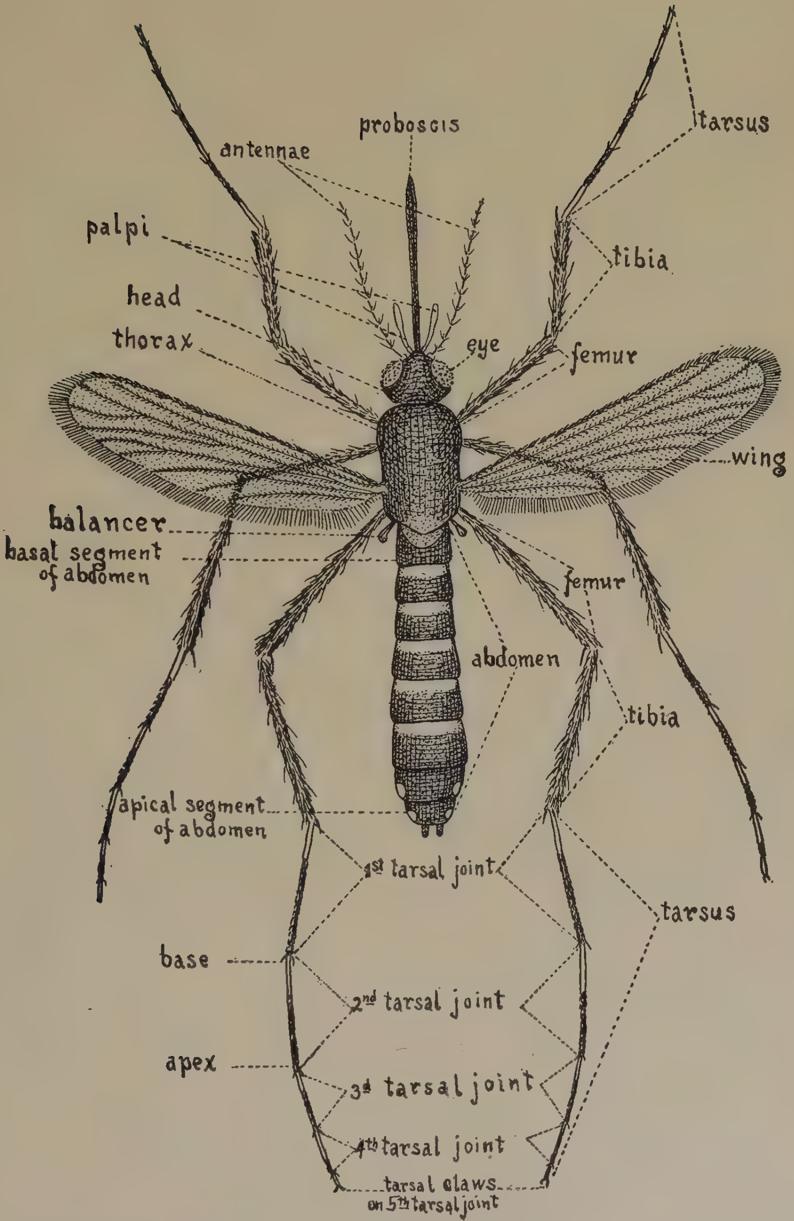

FIG. 75.—An adult mosquito with certain parts used in classification named. (Adapted after J. B. Smith.)

4. Cross veins tending to lie in a line, prespiracular bristles present—*Culiseta* Felt.
   Cross veins separated, prespiracular bristles absent—5
5. Fourth joint of front tarsus very short—*Orthopodomyia* Theob.
   Fourth joint of front tarsus normal—6
6. Second joint of antennæ very long—*Deinocerites* Theob.
   " " " " normal —7
7. Abdomen of female with prominent cerci, side pieces of male prominent—8

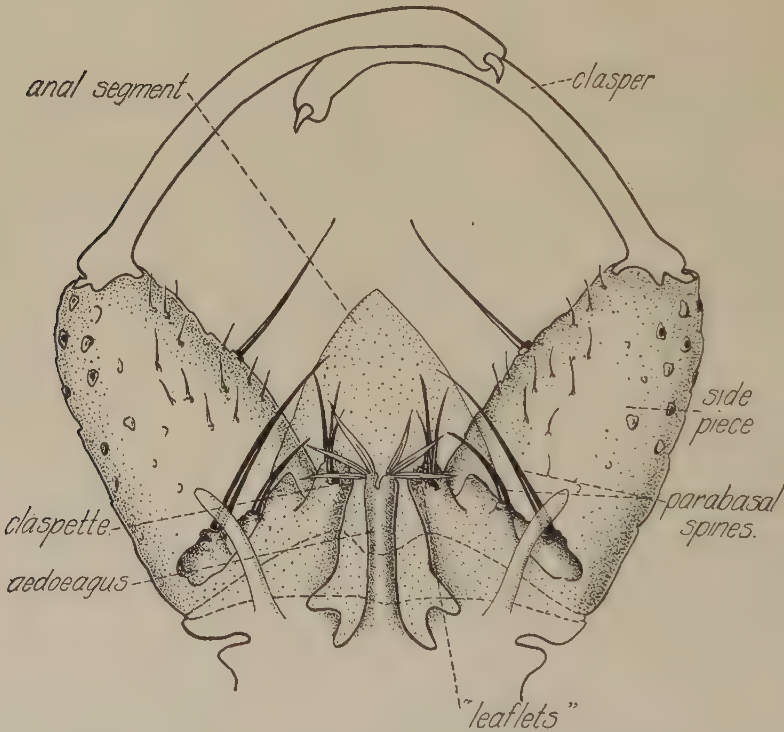

FIG. 76.—Showing male genitalia of Anopheles mosquito; parts used in classification are labelled.

   Abdomen of female with cerci small, side pieces of male downcurved and inconspicuous—9
8. Last segment of female abdomen wholly retracted within the seventh segment, male claspette with multiple appendages—*Psorophora* R.-D.
   Last segment of female abdomen partly retracted within seventh segment, male claspette wanting or with single terminal appendage—*Aëdes* Meig.
9. Wing scales unusually large and broad—*Mansonia* Blanchard
   Wing scales normal—*Culex* L.

Life History.—The length of time required for mosquitoes to develop from egg to imago depends not only on climatic and temperature conditions but also on the species, for there are certain mosquitoes notably mountain species (such as the northern Aëdes) which deposit their eggs in the late spring and early summer and remain in this stage through the next summer and winter thus remaining in this stage for 8 to 9 months. The later stages are rapidly accomplished. In contrast with this very long life history period there is the case of the yellow fever mosquito, and other species as well, which may pass through the entire development in less than 10 days. Low temperatures always result in prolonging the life histories of all rapidly developing species.

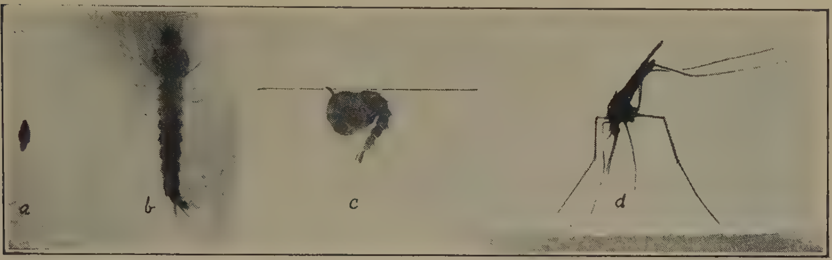

Fig. 77.—Illustrating the life history of a mosquito (*Anopheles maculipennis*). *a.* egg; *b.* larva or wriggler (viewed from above); *c.* pupa or tumbler; *d.* adult. × 5.

All mosquitoes pass through the several stages of a complex metamorphosis,—*egg, larva, pupa* and *imago* (Fig. 77). The larvæ are commonly called "wrigglers" and the pupæ "tumblers." Water in which to pass the larval and pupal stages is essential to development. Eggs in some species may be deposited on mud and the larvæ may exist for some hours in similar situations, however, Howard states that, "In no case were we able to revive larvæ in mud from which the water had been drawn off for more than 48 hours, and after 24 hours only a small proportion of the larvæ revived." Eggs may, on the contrary, in some species survive long periods of desiccation,

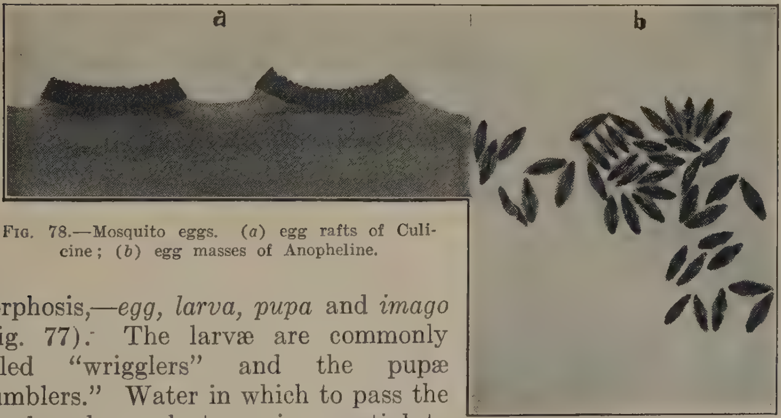

Fig. 78.—Mosquito eggs. (*a*) egg rafts of Culicine; (*b*) egg masses of Anopheline.

notably those of the yellow fever mosquito which will hatch after being dry for a period of 6 months.

Although egg laying in temperate climates is restricted to the spring, summer and early autumn this may occur at all seasons where favorable climatic conditions prevail throughout the year, thus the writer has found eggs of *Culiseta* (*Theobaldia*) *incidens* Thom. every month in the year in the San Francisco Bay region, the incubation period being longer during the winter months.

Mosquito eggs are deposited on the surface of quiet pools of water and along the margins, and even in drier situations where pools may be formed later by rains or tidal action. The culicine species generally lay the eggs in rafts (Fig. 78), the individual eggs (as many as 450) being on end and securely attached to each other by means of a rapidly hardening secretion. Anopheline mosquitoes and the Aëdes, inclusive of the yellow fever mosquito, deposit eggs singly (Fig. 79).

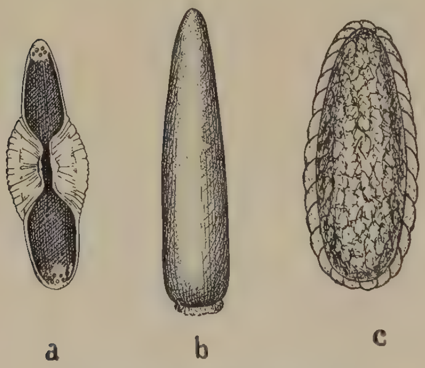

Fig. 79.—Individual mosquito eggs. (*a*) Anopheles; (*b*) Culex; (*c*) Stegomyia.

Mosquito larvæ most commonly observed hang from the surface of the water at an angle (Fig. 80a) with heads down, while the larvæ of the Anophelines lie horizontally just beneath the surface (Fig. 80b). During the larval stage and pupal as well these organisms are air breathing, hence by keeping them completely submerged for a time most species can be drowned like any other air breather. Air is secured through the single anal siphon of the larva and the two so-called air trumpets or funnels of the pupa; the anal gills also provide a means for the utilization of oxygen from the water and young forms undoubtedly take oxygen through the integument of the body.

The larvæ secure food by browsing on the algæ and other tiny organisms (both plant and animal) both living and dead which either grow or cling to the surface, sides or bottom of pools and containers. It is not difficult to observe the movements of these creatures as they squirm about while breathing at the surface or wriggle down to the bottom using their well-developed jaws in nibbling food. Transformation to the pupa stage is accomplished in a remarkably short time and comparatively little time is spent in this non-feeding stage. The term "tumbler" is applied to the pupa because of its tumbling method of locomotion. The emergence of the adult is accomplished while the pupa rests in the water by gradually withdrawing the body through a dorsal split in the pupal skin. The winged insect emerges, balances itself on the empty pupal shell, spreads its wings and is soon off to find food. Undoubtedly many mosquitoes never enjoy the privilege of sucking blood, hence male and female alike (the former do not suck blood) may feed on other liquid substances. Laboratory observations prove that blood-sucking is not absolutely necessary for the development of eggs in certain species.

The longevity of adult mosquitoes under field conditions is not easily determined but observations during control campaigns indicate that the life of the female mosquito during the summer under natural conditions is about 30 days. The male only lives 3 or 4 days, rarely longer under best conditions. Female mosquitoes, of course, hibernate very commonly during the winter months and may thus prolong life several months.

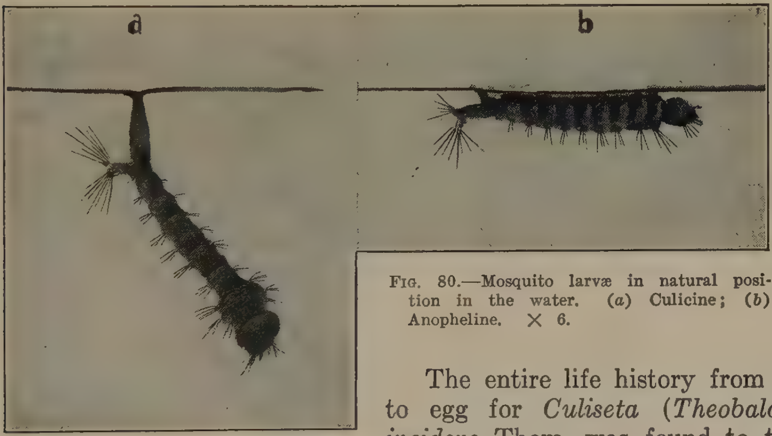

Fig. 80.—Mosquito larvæ in natural position in the water. (*a*) Culicine; (*b*) Anopheline. × 6.

The entire life history from egg to egg for *Culiseta* (*Theobaldia*) *incidens* Thom. was found to take 18 days at a constant maintained temperature of 24° ± 1° C., about 24 hours for the incubation period of the eggs, the larvæ molted on the 2d and 4th day after hatching and again on the 8th day, pupating on the 11th day, giving about 10 days for the larval period, and the mosquito emerged on the second day after pupation requiring about 36 hours for the pupal stage. Howard gives the time for *Culex pungens* Wied. (= *C. quinquefasciatus* Say) as "sixteen to twenty-four hours for the egg, seven days for the larvæ and two days for the pupa."

Internal Anatomy.—To be prepared to study the relation of mosquitoes to such diseases as malaria and filariasis, the student should be familiar with their internal anatomy. The attention of the student is called particularly to the excellent treatise on the "Structure and Biology of Anopheles" by Nuttall and Shipley in the Journal of Hygiene, Vol. III, No. 2, pages 166-215.

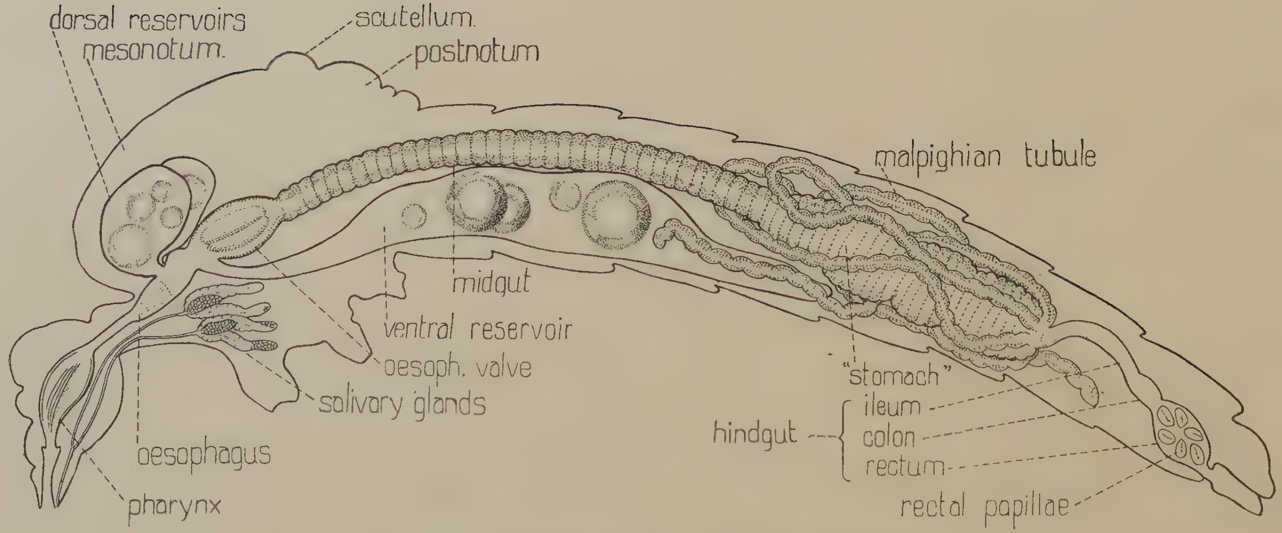

Fig. 81.—Showing internal anatomy of a female anopheles mosquito.

The alimentary canal is separable into three regions, the *fore-*, *mid-* and *hind-gut,* each of which may be arbitrarily subdivided into more or less distinct divisions (Fig. 81). Thus the fore-gut consists of the sucking tube of the *proboscis,* the *pharynx,* including pumping organ and the *esophagus* with its *diverticulæ* (three in number and generally known as food reservoirs); the mid-gut consists of a narrower anterior portion (false proventriculus) and a wider posterior portion (*stomach*) occupying the thorax and much of the abdomen, and limited posteriorly by the origin of the five *Malpighian tubules* which indicate the beginning of the hind-gut; the hind-gut is bent on itself several times and consists of the narrow, longer *ileum,* the *colon* and what is arbitrarily termed *rectum* indicated by the presence of *rectal papillæ.*

The *salivary system* consists of two sets of salivary glands (right and left), three glands to each set (Fig. 81). These organs are situated ventrally in the thorax near the neck. Each set of glands empties into a duct which combines with the opposite one to form the common salivary duct. This common duct empties its contents into the esophagus through the salivary receptacle close to the base of the proboscis.

The *reproductive system* of the female mosquito occupies the posterior portion of the abdomen and comprises a pair of ovaries joined by a pair of oviducts terminating in the *vagina* which opens ventrally in a depression of the ninth sternite; *spermathecæ* are present (1 to 3 depending on the species). The spermathecæ of an impregnated female contain myriads of spermatozoa, and the ovaries when mature occupy the larger part of the abdomen.

ANOPHELINE MOSQUITOES

Adults.—Anopheline mosquitoes as already suggested may be crudely distinguished from the Culicines by the presence of long palpi in both sexes (Fig. 71). The proboscis is always straight and the scutellum is simple, never trilobed. Our commoner species rest with the head downward and abdomen decidedly tilted up (Figs. 82 and 83) except when engorged with blood. The proboscis, head and abdomen are nearly in a straight line. The hum of Anophelines is distinctly low pitched and almost inaudible unless close to the ear.

Most of our commoner Anophelines are not notably strong fliers and are not as a rule carried by the wind inasmuch as they take to cover even in a moderate breeze. If Anophelines are found one can rest assured that their breeding place is somewhere near by, usually within two or three hundred yards, seldom over a mile away. They may of course be transported many miles in railway cars and the like.

The usual method of overwintering is in the adult stage (females only), although some individuals pass the winter in the larval stage buried in mud and debris at the bottom of certain pools. The overwintering adults at least so far as our California observations show may change their places of refuge from time to time and begin to bite freely even at noonday and in bright sunlight as early as the middle of February, about which time they begin a veritable swarming process. Communities in the Sacramento Valley, for example, become literally overrun with them about this time. This is apparently a migratory or dispersal flight when egg deposition is accomplished and all over-wintering forms soon die.

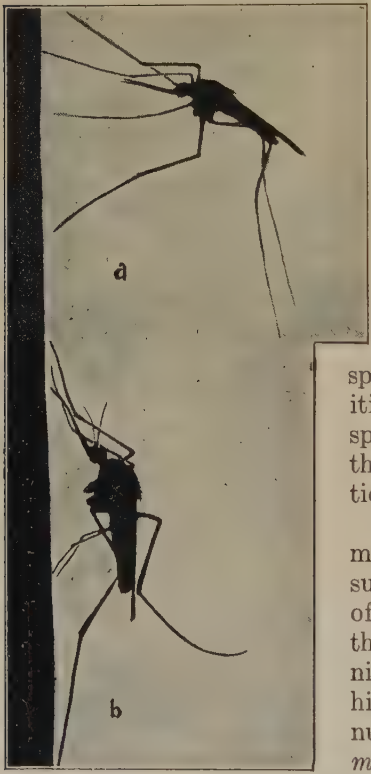

Fig. 82.—Characteristic attitude of adult mosquitoes at rest. *a.* Anopheles with body normally at an angle of from 25° to 55° with the surface; *b.* Culex, with body parallel. × 8.

Egg-laying Habits.—Fertilization of the females takes place immediately upon emergence. The males emerge first and may be seen hovering over or near the breeding places in small swarms apparently awaiting the appearance of the females. Overwintering females are fertilized by the last brood of males during the autumn and the eggs are deposited soon after the spring migratory flight. In certain localities at least there is a period when the species only exists in the larval stage, all the adults having died after egg deposition, probably only a single laying.

Under laboratory conditions the great majority of eggs are deposited between sunset and eleven in the evening (vicinity of Chico, California, May to August), although our records show layings later at night and a few during late afternoons of highly overcast humid days. The average number of eggs deposited by *Anopheles maculipennis* is slightly in excess of 200, with 315 as the highest limit for one laying so far as our observations are concerned. The same average and total number for one laying is closely approximated by *Anopheles punctipennis.* At least three batches of eggs may be laid during the life time of a female. It is of interest to note that in one of our observations a female deposited 174 eggs in 19 minutes, an egg every 6 to 7 seconds with intervening periods of rest. During the entire operation the female resting on the surface of the water remained motionless except for the monotonous jerking of the abdomen when the egg was released. The eggs fell in a heap beneath the insect, pearly white in color, toppling over and forming beautiful patterns and becoming deep brownish black in about 45 minutes.

Morphology of the Eggs.—In comparison with the extensive work that has been done on the morphology and classification of the other stages of the anopheline life cycle, little has been done with the eggs. The characters found to vary in such a manner as to make identification simple, are length of the egg, and position and length of the float. The consideration of one or more of these factors is sufficient to place the egg of local species correctly, but in a larger group it would be necessary to utilize other characters, such as the "frill" of Stephens and Christophers,[1] which encircles the flat or upper side of the egg, the formation of the floats, or the reticular membrane enclosing the egg.

These authors classify anopheline eggs (Fig. 79) into three groups:

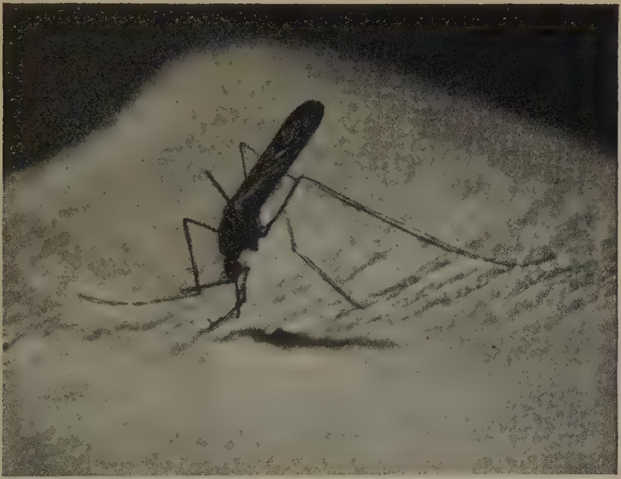

FIG. 83.—*Anopheles maculipennis* in the act of sucking blood from the author's hand.

(1) those with the lateral floats not touching the margin; (2) those whose lateral floats overlap the upper side of the egg; (3) those without floats. According to this classification *A. maculipennis* and *A. punctipennis* fall in the second class and *A. pseudopunctipennis* in the third.

The egg of *A. maculipennis* is fusiform, slightly rounded at each end, and tapering to the extent that one end is slightly broader than the other. The upper surface is flattened with a slight longitudinal concavity while the lower surface is broadly convex, the convexity becoming more pronounced at the broad end of the egg. The upper surface is granular, bordered by a laterally striated frill 16 μ in width, except at the floats, while the lower surface shows, under proper light, a silvery reticulation. Medianly placed are two roughly oval lateral floats, each divided in a majority of cases into twelve scalloped compartments. The larger part of the area covered by these floats is on the lateral faces of the egg, but they project dorsally over the margins which are described as "gunwales" rather aptly by one author who likens the egg to a boat. The eggs range in length from 592 to 656 μ. The floats vary in length from 144 to 224 μ.

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[1] Stephens, J. W. W., and Christophers, S. R., 1908. The Practical Study of Malaria. University Press, Liverpool.

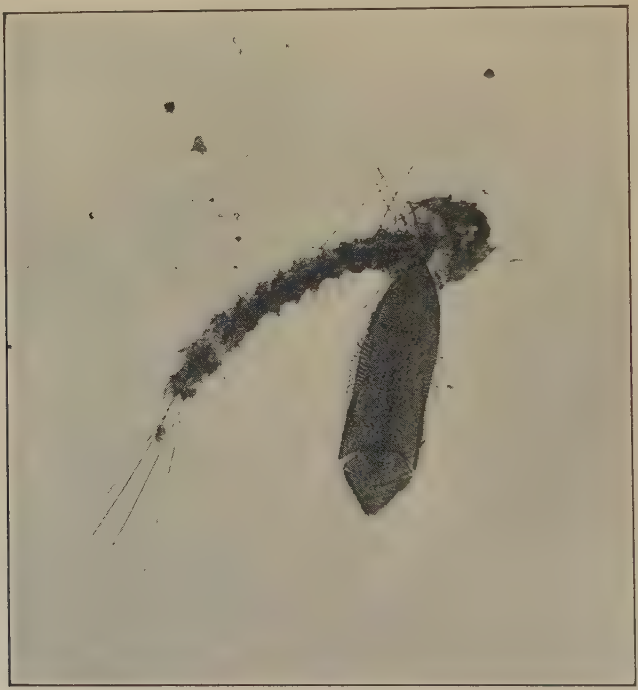

Fig. 84.—Anopheles mosquito larva just emerged from the egg. × 50.

The eggs of *A. punctipennis* resemble those described above with these exceptions, the upper flattened surface is distinctly concave longitudinally, the floats are decidedly wider, projecting dorsally over the margins to the extent that they more nearly meet on the dorsal median line than those of *A. maculipennis*. The floats also include approximately eighteen scalloped compartments each and extend along the sides for slightly more than one-half the entire length of the egg, while in *A. maculipennis* the floats extend for only one-third the length.

The range in length of the eggs of *A. punctipennis* extends from 544 to 576 μ while the float length remains fairly constant at 320 μ.

In *Anopheles pseudopunctipennis* is found a peculiar specialization represented in the general characters of the egg of *A. turkhudi* Liston, which is placed by Stephens and Christophers in class three of their table as lacking floats, although vestiges are present. The eggs are shorter than either of the two already mentioned, ranging from 512 to 528 μ. The upper surface is nearly flat, showing little concavity longitudinally although the lower surface shows a marked convexity. Both ends of the eggs are rounded, one being considerably broader than the other. The floats are represented by a fusiform closely appressed area, approximately 270 μ long, lying on the dorsal side of the egg and nearer the blunt end. This area is divided medianly by a line which is assumed by the author to be the line of contact of the two floats that have been forced up from the sides. Lateral lines mark off each longitudinal half of the area into twelve sections representing the twelve original compartments of lateral floats. This area is so appressed that its position is not distinguishable from a lateral view.

Near the narrow end of the egg the membranous covering flares out from the body of the egg to form a translucent, striated collar which completely encircles the end, with the exception of a triangular incision down the dorsal median line in a manner which reminds one of an "oversized dress collar." The egg hangs at an angle in the water, supported by surface tension on this "collar." The larvæ, however, unlike those of *Anopheles turkhudi,* whose eggs those of *pseudopunctipennis* resemble, retain the horizontal position at the surface of the water.

Selection of Breeding Places.—Much has been written regarding the type of breeding places frequented by various species of Anophelines, and experienced observers in this field are able to forecast with a high degree of accuracy the species that they will find breeding in a given situation. This intuition is almost impossible to analyze and attempts to work out the ecology have yielded as yet only partial explanations. Disregarding the causes that make particular pools acceptable or unfavorable for the life of the larvæ, there remains a fundamental question on which the whole study depends. This is, the determination of whether the selection of the particular pools is due to selective oviposition on the part of the female or the inhibiting effects, chemical or biological, upon the larvæ present in some pools which are unfavorable to the species under consideration.

In the course of our work we have found pools from which there constantly emerged, in the one case *A. maculipennis* and in the other *A. punctipennis* with no mixture of the species. These pools were therefore classified as *maculipennis* pools or *punctipennis* pools. Tests were made by planting eggs of each species in pools hitherto inhabited only by the larvæ of the other species and their development observed. In order to accomplish this under the most natural conditions, "lug" boxes with bobbinet coverings substituted for bottoms were inverted in the pools, supported a little from the bottom by stakes and reaching an equal distance above the surface to prevent overflow. By supporting them a little from the bottom it was hoped that the natural enemies might successfully enter and that the enclosed water would partake of all the conditions prevalent in the pool and still not allow the escape in any appreciable numbers of the surface feeding larvæ. Through an opening in the bobbinet covering, the eggs were gently washed on the surface of the water in the box. Unfortunately our boxes in this experiment were of necessity located in pools subject to the rise of a creek, an occurrence that happened several times in the night owing to thunderstorms in the mountains and the unexpected flow of unused irrigation water. Due to this contingency all of our boxes with the exception of one set were found on one or more mornings to be awash, rendering their results problematical. One set, however, was conducted under optimum conditions. A pool, six by twenty-five feet in area known in our experiments as a *punctipennis* pool, was formed by a receding creek and fed by seepage and a trickling connection with the main stream. It was shaded, cool and thickly overhung with surrounding brush, mainly grape, cottonwood and sycamore. The bottom was made up of water-rounded stones ranging in size from pebbles to small boulders and its prominent vegetable growth was a member of the Crenothrix group. The water was unusually clear and had an alkalinity of 840 parts of $CaCO_3$ per million. It showed evidence of being permanent, in part at least, throughout the summer. Two boxes were installed as mentioned above enclosing a section in which larvæ had been observed and removed. On June 28, 1920, 474 eggs of *A. maculipennis* were placed in one box and on July 1, 635 eggs of *A. punctipennis* were placed in the other. These eggs were observed to hatch (Fig. 84) in the normal period in both boxes and daily observations proved their gradual development, pupation beginning on the thirteenth day after egg deposition. No accurate count of the numbers emerging was possible under the existing conditions, but from general observation, no retardation in development or diminution in the expected numbers of *A. maculipennis*, although breeding in an *A. punctipennis* pool, could be noted. The results of this experiment left to our minds only two alternatives in the question of selective breeding places—either the *punctipennis* larvæ are cannibalistic on the *maculipennis* larvæ when the former are in optimum surroundings, and the process is reversed when optimum conditions are furnished to *maculipennis* larvæ, or what is far more likely—the female exercises selection in depositing her eggs. Several experiments were inaugurated to settle this first alternative by mixing the eggs in one box but the floods mentioned above rendered our results untrustworthy.

Incubation Period.—For *A. maculipennis* the average incubation period is 2.5 days with a range from 2 to 4 days. The eggs of *A. punctipennis* averaged 3.2 days with a range from 2 to 6 days. Temperature is quoted by many authors as distinctly influencing the length of the incubation period. With many of our sets, however, laid on the same day and subjected to the same conditions a considerable amount of variation was recorded. It seems highly probable that temperature should exercise a decided effect on incubation particularly at the extremes but within a certain range such as our eggs were subjected to, i.e., 68° to 76° F., little effect could be noted.

Desiccation Experiments.—Mitchell[1] states that Dr. Dupree "has had the eggs of Anopheles develop after as many as ten hours out of water, this, however, being exceptional." Stephens and Christophers (1908, *loc. cit.*) state that anopheline eggs removed from water, placed on paper and allowed to dry for more than 2, or, at the most, 3 days, will not hatch if they are kept at a temperature of 86° to 96° F. In an attempt to check these findings for the Californian species, eggs of *A. maculipennis* and *A. punctipennis* were removed from the water 6 hours after they had been deposited by allowing them to adhere to the surface of a strip of filter paper dipped among them, leaving a number of eggs in the jar as a check. The filter paper was then suspended by pins inside a capsule box and allowed to dry out at room temperature. Drying was accomplished in a remarkably short time for at the end of 4 hours the paper was entirely dry and the eggs rattled off its surface at the least movement. At intervals of 24 hours a supply of dried eggs were taken from the filter paper and placed in shell vials of tap water. We were never able to obtain a hatch from eggs of *A. punctipennis* that had been removed from water for 24 hours. However, with *A. maculipennis* eggs removed from the water on June 14, dried and replaced on the 15th, 16th and 17th, having been subjected to drying for 24, 48 and 72 hours, respectively, there were produced excellent hatches on the 17th, 18th and 19th, showing not only that the eggs of this species can withstand drying for these periods, but also the rather interesting fact that development ceases as soon as they are removed from the water. Eggs from this lot placed in water on the 18th (96 hours of drying) and for several succeeding days failed to hatch. The maximum and minimum temperatures to which the eggs were subjected during this period were respectively 74° F. and 65° F. Another attempt to duplicate this set of experiments with the same species and technique when the temperature ranged between 70° F. and 80° F. resulted in the failure of the eggs to hatch after 48 hours of drying.

[1] Mitchell, E. G., 1907. Mosquito Life, xxii + 281 pp. New York, Putnam's.

Biting Habits.—That certain species of mosquitoes predominate indoors or are the sole intrants must be weighed against the production and proximity of these and others under comparison. Carter, Le Prince and Griffiths[1] have observed that *Anopheles quadrimaculatus* is much more often found in residences than *A. punctipennis.* Mitzmain[2] in a table comparing the collections of *A. punctipennis* and *A. quadrimaculatus,* totaling 1,377 specimens, compares the numbers of each species taken inside dwellings, under dwellings, privies, vacated buildings, cattle sheds, horse and mule sheds, fowl roosts and wagon and tool sheds. In commenting on his results he states:

> "It is indicated that in the three sources of direct human influence, namely, inside dwellings, under dwellings and in privies, the last produced the greatest number of *A. punctipennis.* This species comprised less than one-third (30 per cent) of the catch in houses, while under dwellings 62 per cent of the mosquitoes proved to be *A. punctipennis.* . . . It has been observed by service officers, conducting malarial surveys, that although *A. punctipennis* rarely bites while inside a dwelling, it is found to attack persons seated on the porch or gallery of the house, after which these mosquitoes seek rest, presumably under the house in preference to the interior."

Mitzmain also cites Ross (1910, *loc. cit.*) viz.: "Ross states that *Anopheles* (*Pyretophorus*) *costalis,* a malaria carrier incriminated experimentally in Mauritius, prefers verandas to inner rooms and also bites in the open."

During the summer of 1920, from May 12 to July 13, daily collections of mosquitoes were made by the writer and his associates at Vina (Northern Sacramento Valley, California), one series being indoors and the other outdoors. The indoor collections were made regularly in the same buildings consisting of a cowshed, a washhouse, showerbath, storehouse and dwelling, while the outdoor collections were made under a short wooden bridge within ten to twelve feet of an aggregation of shacks occupied by Chinese and negroes. The indoor series taken in an area where control measures were in progress does not represent a large number of mosquitoes but the fact remains that of 77 anophelines taken, 50 were *Anopheles maculipennis* (including only 1 male) and 27 were *A. punctipennis* (including 2 males) or practically twice as many of the former. On the other hand, the outdoor series represented a total of 343 anophelines of which 102 were *A. maculipennis* (42 males and 60 females) and 241 were *A. punctipennis* (130 males and 111 females) or something over twice as many as the latter.

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[1] Carter, H. R., Le Prince, J. A. A., and Griffiths, T. H. D., 1916. Impounded water. U. S. Public Health Bull. No. 79, 34 pp.

[2] Mitzmain, M. B., 1917. Anopheline mosquitoes, their distribution and infection under field conditions. U. S. Public Health Service. Reprint No. 393. (U. S. P. H. Report, April 13, 1917.)

These collections bear out very well the general observations that *A. maculipennis* like *A. quadrimaculatus* is typically an invader of houses and consequently of greater importance as a malaria carrier, while *A. punctipennis* is chiefly an outdoor biter, porch biter, etc., and consequently probably of less importance as a malaria carrier. During the entire period of two months the well screened cottage which was occupied by our party was not invaded a single time by *A. punctipennis* while *A. maculipennis* was a common visitor.

TABLE III

Key to the Species of Adult Anopheles Mosquitoes

(After Howard, Dyar and Knab)

1. Tarsi ornamented with white or yellow........................ 2
Tarsi wholly dark colored.................................... 13
2. Hind tarsi with a series of rings............................ 5
Hind tarsi all white beyond second joint...................... 3
Hind tarsi white beyond second joint, a black spot on the last joint 4
3. Abdomen dorsally covered with scales....*argyritarsis* Robineau-Desvoidy
Abdomen clothed dorsally with hairs only.................*lutzii* Cruz
4. Palpi with the last two joints white except narrowly at bases *tarsimaculata* Goeld.
Palpi with the last joint only white................ *albimanus* Wied.
5. Hind tarsi with small basal rings only; palpi wholly black scaled *grabhamii* Theo.
Tarsi more conspicuously ornamented; palpi not wholly black scaled 6
6. Tarsi and tibiæ narrowly ringed and speckled black and white or yellow 8
Hind tarsi with broad apical segmental white rings, not speckled.. 7
7. Wings with four white spots on the costa.......... *bellator* D. and K.
Wings with two white spots on the costa, five on the first vein *neivai* H., D. and K.
8. Wing scales mostly blackish, many little patches of yellow ones *vestitipennis* D. and K.
Wing scales black and white or yellow, several large concrete patches of black scales.. 9
9. Hind tarsal joints with apical rings, the last joint wholly black *maculipes* Theo.
Hind tarsi with rings involving both ends of the joints, last joint mostly or wholly pale scaled................................ 10
10. Wing scales broad and rounded................................ 11
Wing scales narrowly ovate to lanceolate...................... 12
11. Tarsi yellow with small black dots............. *mediopunctatus* Theo.
Tarsi black with white rings.................. *malefactor* D. and K.
12. Hind tarsi with numerous yellow rings....... *strigimacula* D. and K.
Hind tarsi with sparse white rings.......... *apicimacula* D. and K.
13. Hind tibiæ broadly white at apex........................ *eiseni* Coq.
Hind tibiæ without white apical ring.......................... 14
14. Wings with a white spot at outer third of costa............... 15
Wings without such spot on the costa.......................... 16

15. Palpi marked with white; third vein extensively white in the middle *pseudopunctipennis* Theo.
    Palpi wholly black scaled; third vein wholly black scaled *punctipennis* Say
16. Wings with patches of yellowish scales, sixth vein with three black spots .... *crucians* Wied.
    Wings without patches of pale scales......................... 17
17. Wing at apex with a coppery spot on the fringe *occidentalis* D. and K. [*maculipennis* Meig.]
    Wing-fringe uniformly dark throughout........................ 18
18. Body blackish throughout, hair-scales of mesonotum dark brown *atropos* D. and K.
    Body not wholly blackish, hair-scales of mesonotum yellow or white 19
19. Palpi of the female with dull silvery white rings at the bases of the joints; scales of wings not distinctly massed at bases of fork-cells .... *walkeri* Theo.
    Palpi of the female blackish scaled throughout; scales of wings massed to form distinct spots at the cross-veins and at bases of fork-cells .... *quadrimaculatus* Say

Key to the Species of Anopheles Larvæ
(After Howard, Dyar and Knab)

1. Comb of the eighth segment with the teeth all long, equal *neivai* H., D. and K.
   Teeth of the comb alternatingly long and short. *malefactor* D. and K.
   strigimacula D. and K.
   Teeth of the comb both long and short and irregular........... 2
2. Abdomen with seven pairs of dorsal fan-shaped tufts, the pair on first segment small........ *albimanus* Wied.
   tarsimaculata Goeld.
   Abdomen with six pairs of fan-shaped tufts..................... 3
   Abdomen with five pairs of well-developed tufts................. 5
3. Elements of the fan-shaped tufts slender, smoothly pointed *argyritarsis* Rob.-Desv.
   Elements of the fan-shaped tufts notched toward tip............... 4
4. Fan-shaped tufts all equal in size.........................*eiseni* Coq.
   First pair of tufts small...................... *punctipennis* Say
   quadrimaculatus Say
5. First and last pair of fan-shaped tufts smaller than the others *crucians* Wied.
   Fan-shaped tufts all equal...................................... 6
6. Elements of fan-shaped tufts with long slender apical portion *pseudopunctipennis* Theo.
   Fan-shaped tufts with normal elements........ *occidentalis* D. and K.
   (*maculipennis* Meig.)
   grabhamii Theo.

Aëdes Mosquitoes

Yellow Fever Mosquitoes.—Although the yellow fever mosquitoes will long be known under the specific name of *Stegomyia fasciata* Fabr., the species is apparently correctly designated as *Aëdes ægypti* Linn., having stood for several years under the name of *Aëdes calopus* Meig.

This species is widely distributed within the limits of 40° N. and 40° S. latitude, but is highly susceptible to temperature variations. According to Hindle[1] it soon dies in the open air at a temperature of 7° to 8° C., succumbing in a few seconds to an exposure of 0° C., and 37° C. is rapidly fatal. Furthermore, it does not thrive in dry hot climates. The adult insect is beautifully marked with silvery white or yellowish white bands and stripes on a nearly black background, whence the name "tiger mosquito." It has a "lyre-like" pattern dorsally on its thorax, i.e., two outer curved yellowish white lines and two median parallel lines (Fig. 85d). The legs are conspicuously banded and the last joint of the hind leg is entirely white. The head is covered with broad flat scales with only a single row of upright forked scales.

The yellow-fever mosquito is a typical domestic species seldom being found far from buildings. Many observers believe it to be a day flying and day feeding species, but this habit apparently is restricted to the younger individuals up to six or seven days after emergence or rather until a meal of blood is secured when the insect becomes nocturnal. Howard observes that "it prefers the blood of white races to that of dark races, and attacks young, vigorous persons of fine skin and good color in preference to anemic or aged people."

The eggs of the yellow-fever mosquito are deposited singly, are dark in color and each egg is surrounded by air cells (Fig. 79c). Comparatively few eggs are deposited at one laying, i.e., from perhaps less than fifty to a hundred, and there may be several layings.

Unlike the eggs of most species these can withstand desiccation to a very marked degree, some authors declaring that this is possible for several months. Ordinarily the eggs hatch in about 48 hours.

The larvæ are quite robust, the breathing siphon is comparatively short and heavy and black (Fig. 85b), and their position in the water is almost vertical, considerably more so than other Culicine species. The larval stage is ordinarily passed in about 9 or 10 days under average conditions.

The pupæ are characteristically Culicine; the breathing trumpets are, however, broadly triangular. Only about 36 hours is spent in this stage.

According to Howard the shortest period of development from egg to imago observed by Reed and Carroll in Cuba was 9½ days, viz.: egg stage, 2 days; larval stage, 6 days; pupal stage, 36 hours. From this very short period the time ranges from 11 to 18 days according to the same author.

The yellow-fever mosquito breeds by preference in artificial pools of rain water. (They are known, however, at times to breed naturally in brackish water.) Rain-water barrels, tanks, cisterns, tin cans, urns,

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[1] Hindle, Edw., 1914. Flies in relation to disease,—blood-sucking flies. Cambridge University Press, XV + 398 pp.

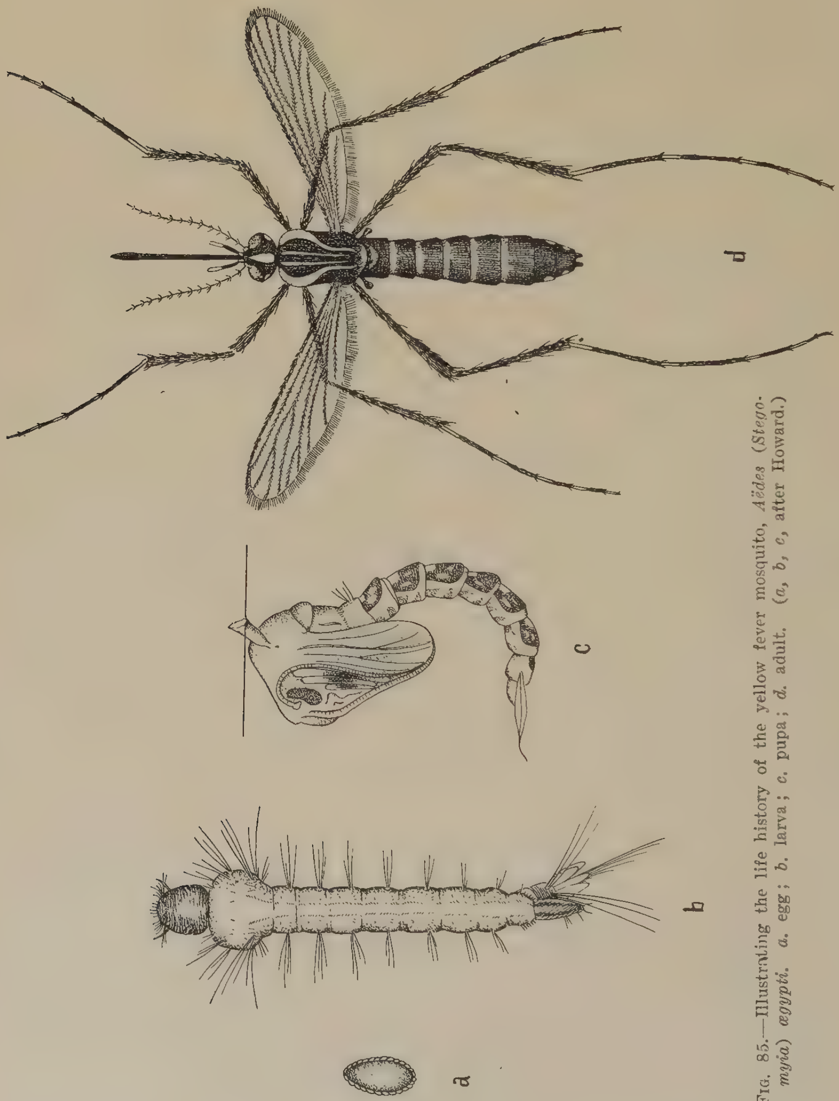

FIG. 85.—Illustrating the life history of the yellow fever mosquito, *Aëdes* (*Stegomyia*) *ægypti*. *a.* egg; *b.* larva; *c.* pupa; *d.* adult. (*a*, *b*, *c*, after Howard.)

etc., provide suitable places, also water collected between the leaves of certain members of the Agave family; ornamental banana palms are often a great menace in this respect.

Salt Marsh Mosquitoes.—Where mosquitoes are abundant and annoying even in broad daylight in the vicinity of salt marshes[1] surveys usually prove that practically all of the trouble is traceable to one or more species which breed in salt or brackish water. The adults of the salt marsh species are notable migrants, allowing themselves to be drifted in great swarms for many miles by the wind, traveling twenty-five to thirty miles. The principal salt marsh species of the Atlantic coast of the United States are *Aëdes sollicitans* Walk., known as the white-banded salt marsh mosquito, *Aëdes cantator* Coq., the brown salt marsh species, and *Aëdes tæniorhynchus* Wied., the small salt marsh mosquito. The eggs are laid on the mud of salt marsh pools and hatch when the pools fill with water. "About a week is required in warm weather from the hatching of the egg to the emergence of the adult mosquitoes. . . . The banded salt marsh mosquito is far more abundant than the brown salt marsh species, and appearing later in the summer, constitutes the mosquito plague of the shore region." (New Jersey northward.)

The salt-marsh species of our Pacific Coast[2] are mainly *Aëdes squamiger* Coq., *Aëdes dorsalis* Meig. (= *curriei* Coq. = *A. onondagensis* Felt = *A. lativittatus* Coq.), and *Aëdes tæniorhynchus* Wied. *Aëdes dorsalis* is not wholly a salt-marsh breeder being found often in enormous numbers in flood waters near rice fields and other alkaline water. The eggs are laid in the mud of pools formed by the monthly high tide, and which partly or wholly dry up before the successive high tide reaches them. When the eggs are submerged in water the larvæ hatch in 2 to 4 days and development proceeds rapidly, the emergence of adults taking place in 7 to 8 days or over depending upon temperature. Broods appear rather regularly once a month, although the adults do not all emerge from eggs laid at the same time, overlapping of egg layings taking place. The eggs remain over winter, the first larvæ appearing in the following February or March. They may also pass the winter in the larval stage.

The numbers of larvæ appearing in certain pools is almost unbelievable. Smith states:

> "I have found pools so crowded that an estimate of 100 wrigglers in an area of one square inch was scarcely equal to the fact. Half that number is a common occurrence. This means over 7,000 in an area of one square foot, and it needs an area of less than 150 square feet—a pool

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[1] Smith, John B., 1902. The salt marsh mosquito, *Culex sollicitans* Wlk. New Jersey Agric. Exp. Sta. Special Bulletin T.

[2] Quayle, H. J., 1906. Mosquito control work in California. Univ. of Calif. Agric. Exp. Sta. Bull. No. 178.

roughly ten by fifteen feet—to produce 1,000,000 mosquitoes at one hatching. If these figures seem incredible they can be easily verified anywhere along shore by anyone who will put on a pair of gum boots and will hunt out a few breeding places."

Two Aëdes mosquitoes not included in the above section possess breeding habits of unusual interest. (1) *Aëdes vexans* Meig., a typical *fresh* water flood breeder inhabiting temporary wooded swamps; (2) *Aëdes varipalpus* Coq. which lays its eggs above the margins of water collected in tree holes, the larvæ hatching when the water in the holes reaches their level. The adults bear a striking superficial resemblance to the yellow-fever mosquito.

Boreal Aëdes or Snow Mosquitoes.—An interesting group of Aëdes consists of the so-called snow mosquitoes which appear in the early spring in the high mountains and northern ranges of distribution, breeding in the pools left by the melting snow. These Aëdes have but one generation and appear in enormous swarms in the higher elevations and northern ranges much to the dismay of the huntsman and alpine traveler. These mosquitoes have been collected in many localities in the Sierra Nevada by the writer and the following quotations are taken from an interesting account of the same by Dyar.[1]

"At an altitude of 6,000 feet, pupæ were abundant May 25 and by the first week in June the breeding was complete; even the pools that still contained water or had only just thawed out were empty. Adults appeared by the first of June, and by the 15th the woods were filled with them in all directions.

"Speaking especially of the Fallen Leaf Lake region (vicinity of Lake Tahoe) a region in the heart of the Sierras to the north of the high peaks and on the eastern side of the divide, *A.* (*communis*) *tahoënsis* is the commonest and earliest species, found everywhere, both in the hills and the pines in level country. It breeds in the earliest pools of clear water held in rocky land, its home being in the mountains, but it soon spreads everywhere. It was common in the early pools at the head of Fallen Leaf Lake, being often the only species present. It also bred in wave-pools at the lower end of the lake. Dispersal of the adults was in general downward, they being abundant in the pines at Tallac on June 17, though no breeding places were near. *A. cataphylla* is less abundant and less widely dispersed at Fallen Leaf. It was commonest at the foot of the trail to Angora Lakes at the head of the lake, rare at the outlet of the lake and absent at Tallac on Lake Tahoe. *A. hexodontus* breeds in early pools, but especially those of a marshy character, larvæ being taken from hoofprints of cattle in the edge of a marsh. The adults were well distributed and toward the end of June replaced *A.* (*communis*) *tahoënsis* as the dominant species. *A. ventrovittis* is a rare species, taken only at one place near the outlet of Fallen Leaf Lake and then in small numbers. It is presumably a marsh breeder, though the larvæ were not found. *A. palustris* breeds in open grassy marshes, not in large numbers. Dispersal was general, adults being taken everywhere, although seldom commonly. *A. increpitus* is the slowest breeder of any of the early species, the larvæ lingering after all the others are gone, frequently in the same pools. They were abundant at the outlet of Fallen Leaf Lake with a downward dispersal, the adults being common at Tallac, about 2 miles from the breeding places, while only found a quarter of a mile up the lake and many days later.

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[1] Dyar, Harrison G., 1916. New Aëdes from the mountains of California. Insec. Inscit. Mens., Vol. IV, Nos. 7-9, pp. 80-90.

"The seasonal appearance of these mosquitoes varies with the altitude in the ratio of about a month in time to 1,000 feet of elevation. At Yosemite, at about 5,000 feet, all the species were about a month earlier than at Lake Tahoe, at 6,000 feet, while at Summit, at 7,000 feet, they were still another month later, larvæ and pupæ of *tahoënsis* and *hexodontus* being taken there on July 2, 1916, about the same stage that they were taken at Fallen Leaf on June 1, 1916."

CHAPTER X

MOSQUITOES AS DISEASE BEARERS

A. Malaria

Malaria.—Malaria is a widely distributed disease, prevalent to a greater or less degree on every continent. Its presence is dependent upon a complex of environmental factors favorable to the development of large numbers of malaria-bearing mosquitoes as well as to the parasites causing the disease. Temperature and humidity are important factors and a mean summer isotherm of 15° to 16° C. in general covers its geographical distribution fairly well. Although the lowlands are as a rule more likely to be affected, such may not actually be true in all cases because of the absence of one or more important factors, and the disease may occur at high elevations under favorable circumstances, thus the writer found endemic cases of malaria in California at an elevation of about 5,500 feet.

Few diseases have so large a list of synonyms, a few of the common ones being ague, chills and fever, jungle fever, paludism, marsh fever, remittent fever, intermittent fever, *Wechselfieber*, *Kaltesfieber*, etc. The symptoms even though slight, are usually manifested in the form of a more or less regularly appearing paroxysm consisting of three fairly well-defined stages, viz.: the *cold stage* (the chill) in which the skin becomes pale and has the appearance of "gooseflesh," the patient's teeth may chatter, and he may shiver more or less violently; the next stage is the *hot stage*, or fever, the temperature rising during the chill, the skin is hot and flushed; the third stage is marked by the appearance of a general perspiration, the fever falls, and the temperature approaches normal. The entire paroxysm may last but a few hours. In many cases the stages are not so well marked, neither do the paroxysms recur at exactly the same interval,—the latter depends largely on the type of infection.

The disease is caused by blood-inhabiting Protozoa belonging to the genus Plasmodium. These parasites attack the red corpuscles, destroying the same while reproducing asexually; this asexual reproduction or sporulation occurs at fairly regular intervals, i.e., 24, 48, or 72 hours, depending upon the species of Plasmodium involved, the paroxysm resulting at corresponding times. The destruction of vast numbers of red corpuscles results in anæmia. That the paroxysm is due more particularly to the sudden liberation of a toxin and waste products resulting from the intracorpuscular parasites, is now generally believed.

Historical.—Malaria, though not receiving its name until the middle of the eighteenth century, has been known for many centuries, Hippocrates having divided periodic fevers into the quotidian (daily), tertian (every third day) and quartan (every fourth day). The fable of Hercules and the Hydra is believed to refer to malaria, and the disease is mentioned in the Orphic poems. The successful treatment of malaria dates back previous to the seventeenth century. The Countess del Cinchon, the wife of the Viceroy of Peru, is said to have been cured of fever in 1638 by the use of the bark from a certain tree. This bark was introduced into Europe in 1640, and in 1741 Linné named it "cinchona" in honor of the Countess del Cinchon. In 1753 Torti named the disease "malaria," believing it to be air borne and emanating from the bad air (*mal aria*) rising from swamps and marshes.

The credit for the discovery of the causative organism belongs to Laveran, a French army surgeon who was then stationed in Algeria. This discovery was made in 1880. Although the mosquito transmission theory is said to have been held for many years among the Italian and Tyrolese peasants and the natives of German East Africa, the first well formulated mosquito-malaria theory was advanced by King in 1883. In 1885 Golgi discovered that the periodicity of the fevers corresponded to the periodic sporulation of the Plasmodium.

Nuttall (1899) refers to the interesting fact that the malaria-mosquito theory has been repeatedly rediscovered by writers in various countries, e.g., Laveran mentioned the theory as early as 1884, Koch (according to Pfeiffer) in 1892, Manson more particularly in 1894, Bignami and Mendini in 1896 and Grassi in 1898.

The greatest discovery in the history of malaria (as evidenced by the fact that two Nobel prizes have been awarded the discoverer) was made by the Englishman, Major Ronald Ross, in 1898, then stationed in India. Ross demonstrated beyond doubt the important rôle played by mosquitoes in the transmission of malaria, and mankind owes no greater debt to a fellow man than this. Late in the same year Grassi proved that malaria can only be transmitted by a particular kind of mosquito, namely, Anopheles.

In 1900, at the suggestion of Sir Patrick Manson, Doctors Sambon and Low built a mosquito-proof hut in the Roman Campagna, in which they lived during the most malarial months of that year without contracting malaria. At this time these investigators sent infected Anopheles mosquitoes from the Campagna to London, where Dr. Manson's son, Dr. P. Thurburn Manson, and Mr. George Warren permitted themselves to be bitten by these mosquitoes and in due time became ill with the disease.

The use of oil as a factor in mosquito control dates back to the beginning of the nineteenth century; however, the present extensive use of kerosene for this purpose is due largely to the efforts of Howard, beginning in 1892.

While certain German investigators claimed to have reared the malaria parasite *in vitro* previously, it appears that the first recorded successful attempts to accomplish this were made by Bass in 1911.

Circumstantial Evidence.—Immediately following great spring floods when the lowlands become inundated and the receding water leaves behind it innumerable pools there is always much more malaria than usual, a fact always predicted. Coincidentally mosquitoes are unusually abundant, and especially the noiseless kind (presumably Anophelines). Exceedingly warm moist seasons always bring more malaria while a prolonged drought is commonly said to kill the disease, as does the approach of cold weather.

A very common suggestion made to escape malaria is to keep out of the "night air" and close windows and all openings which might permit the "night air" to enter.

In localities where anti-mosquito campaigns have been waged with vigor there has quickly followed a decrease in malaria, no other precautions having been taken.

The circumstantial evidence against the mosquito (in a broad sense) may be summed up as follows:

(1) Malaria exists endemically in districts where mosquitoes are present (all species except the Anophelines are eliminated experimentally); (2) malaria does not exist endemically where there are no mosquitoes (existing cases are without exception traced to an earlier visit on the part of the patient to some locality in which mosquitoes of the Anopheline type occur); (3) persons protecting themselves against mosquito bites while dwelling in malarial districts (otherwise living as do the natives) do not contract malaria; (4) communities previously noted for malaria have been practically freed from this disease when efficient drainage (sewer) systems have been installed; (5) properly conducted mosquito crusades result eventually in the control of malaria in that district.

It may be said that malaria may be wholly absent in the presence of an abundance of mosquitoes. In answer to this it may be replied that there are several hundred species of mosquitoes, of which number usually only one or two species for any one locality are capable of transmitting malaria. Hence, first, the mosquitoes in such localities are probably all non-malaria-bearing, with the entire absence of the malaria-bearing species (Anopheline), or secondly, if Anopheline mosquitoes are present, they have not become infected because of the absence of persons affected with malaria, i.e., malaria must first be introduced before the Anopheline mosquitoes can carry it from person to person, or the number of Anophelines is too small to be of public-health importance.

Experimental Evidence.—The parasite of malaria can easily be seen by examining microscopically properly stained blood from infected persons. The disease can be produced experimentally in healthy persons by inoculation with parasitized blood taken from a malarial patient.

Malaria is popularly believed to be present in certain sources of drinking water, also in overripe fruit, etc. This belief was held in two communities in California in which it was proposed to control the disease by combating mosquitoes. The sanitary inspectors as a demonstration to the people, drank this water, ate freely of the ripest fruit and were exposed to the severest heat of the day and remained free from malaria, having exercised the proper night precautions. That miasma from swamps has no direct relation to malaria was proved by Sambon and Low, as already noted.

It is well known that blood taken directly from a patient suffering from malaria may show flagellated parasites. Ross, in 1895, in his Indian observations found these flagellated bodies in the intestines of mosquitoes which had fed on the blood of malarial patients. Many experiments were made and hundreds of mosquitoes examined during the next few years by Ross. The most striking condition found in some of these mosquitoes was the development of pigmented cells in the stomach wall, the pigment corresponding to malaria pigment. Some of these mosquitoes gave positive results, while the majority gave negative results. Those which furnished positive results were of a particular species, and this gave the clew that the malaria parasite required a particular species of mosquito to serve as intermediary host. The connection between the flagellated bodies and the pigmented cells was furnished by MacCallum in 1898. He found that the function of the flagellated cells was that of an impregnating body; that each flagellum, of which there were several to each cell had the ability to impregnate a spherical parasite. MacCallum's observations were made on the Proteosoma of birds, also known as "bird malaria." Using the Proteosoma as a basis for his further observations, Ross found that the pigmented cells, migrating through the stomach wall of the mosquito[1] and encysting just beneath the peritoneal lining, grew steadily for 3 or 4 days, forming spindle-shaped bodies, which were shed into the body cavity and in 5 or 7 days after feeding were found in vast numbers in the salivary glands.

Grassi's experiments in the Roman Campagna and Sicily proved that human malaria was carried solely by Anopheline mosquitoes.

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[1] It should be noted here that certain Culicine mosquitoes (e.g., *Culex pipiens*) are the transmitters of *Proteosoma* though inefficient as transmitters of *Plasmodium* or human malaria.

According to Nuttall one of the early experiments of Grassi and Bignami was conducted somewhat as follows: Three species of mosquitoes, *Culex penicillaris, Culex malariæ* and *Anopheles claviger* (= *A. maculipennis*) were collected in a malarial district, Maccarese, twenty-two miles from Rome. The insects were then allowed to bite a patient (who consented to the experiment) in the Santo Spirito Hospital (Rome). The patient had never had malaria. In addition to the bites from the imported insects the man was also subjected to the bites of mosquitoes emerging from larvæ placed in the room occupied by him at night. A new supply of larvæ was placed in the room every 4 to 6 days. In due time the man acquired estivo-autumnal malaria as evidenced by the appearance of parasites in his blood. Grassi believed that the disease was due to the bites of *Culex penicellaris* because it was the most numerous, while *Anopheles maculipennis* was present in very small numbers. Nuttall remarks that the infection could only have been produced by the latter, as has been determined since.

After describing the conditions under which Sambon and Low lived in the Roman Campagna while experimenting with malaria, Manson[1] writes as follows:

> "Whilst this experiment was in progress mosquitoes fed in Rome on patients suffering from tertian malaria were forwarded in suitable cages to the London School of Tropical Medicine, and on their arrival were set to bite my son, the late Dr. P. Thurburn Manson, and Mr. George Warren. Shortly afterwards both of these gentlemen, neither of whom had been abroad or otherwise exposed to malarial influences, developed characteristic malarial fever, and malarial parasites were found in abundance in their blood, both at that time and on the occurrence of the several relapses of malarial fever from which they subsequently suffered. The mosquito-malaria theory has now, therefore, passed from the region of conjecture to that of fact."

The Parasite.—The malarial parasites (Plasmodia) belong to the lowest forms of animal life, the Protozoa (Subphylum Sporozoa, Class Telosporida, Subclass Hæmosporida). The pigment of these red-blood-corpuscle-inhabiting parasites is dark and characteristic and properly termed melanin. The presence of the parasites usually gives rise to a periodic chill and fever, due to their periodic asexual reproduction (sporulation) and the liberation of a toxin in the human blood as already explained.

To detect the presence of the parasite a drop of blood is drawn from the lobe of the patient's ear or finger tip, after proper cleansing with alcohol; the droplet of blood is lightly touched with a glass microscopical slide, upon which a film (smear) is made by gently and evenly spreading the droplet by means of a needle or edge of another slide. The film is then fixed for a minute or two in equal parts of alcohol and ether (Rivas) and stained, using Romanowsky modifications, such as Wright, Leishman, Giemsa and Jenner, or by Rivas' method for two or three minutes in diluted borax-methylene-blue, and washed freely for a few moments. If parasites are present in the blood, they should be visible after careful microscopical examination as pigmented intracorpuscular bodies in the form of signet rings, ameboid bodies or as crescents in estivo-autumnal fever of ten or more days' duration. Microscopic examination under an oil immersion lens is necessary, though crescents can easily be seen with lower powers.

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[1] Manson, Sir Patrick, 1909. Tropical Diseases. Cassell and Company (London), xx + 876 pp.

The ease with which parasites can be discovered in a blood smear depends on several important factors,—first, on the length of time that the patient has had malaria, and secondly if he has lately taken quinin the chances for the discovery of parasites are greatly reduced. Ross[1] states that the parasites "will not generally be numerous enough to cause illness unless there is at least one parasite to 100,000 hæmatids; that is, 50 parasites in 1 cmm. of blood; or 150,000,000 in a man 64 kilograms in weight. . . . Such calculations demonstrate the absurdity of supposing that there are no plasmodia present in a person because we fail in finding one after a few minutes' search. As a matter of fact, even if as many as 150,000,000 plasmodia are present in an average man, the chances are that ten to fifteen minutes' search will be required for each plasmodium found; while if we are careless or unfortunate, we may have to look much longer."

The various types of malaria are due to the fact that there are several species of parasitic plasmodia, each of which produces specific symptoms. Three or possibly four distinct types are usually recognized: (1) *Æstivo-autumnal* or *Sub-Tertian;* (2) *Tertian* or *Benign Tertian;* (3) *Quartan,* and (4) *Quotidian.*

a. Plasmodium falciparum Welch (*Plasmodium præcox* Dofl., *Hæmamœba præcox* Grassi and Feletti) is the causative organism of *estivo-autumnal* fever (subtertian or pernicious malaria) of the tropics and subtropics, and is the most severe form of this disease often resulting fatally. Although it is *tertian* in form there is considerable irregularity in the occurrence and duration of the febrile stage owing to a corresponding irregularity in the sporulation of the parasites. The infected red corpuscles are usually normal in size, though some may be slightly shrunken. The intracorpuscular parasite (*trophozoite*) in all its stages is small (not over two thirds size of corpuscle) and fairly ovoid in outline, the melanin (pigment) being less abundant than in either *Plasmodium vivax* or *P. malariæ* and there is present in the corpuscle a sparse coarse granulation known as *Maurer's dots.* The

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[1] Ross, Ronald, 1910. The Prevention of Malaria. E. P. Dutton & Company, New York, xx + 668 pp.

signet ring is thin and small and the chromatin dot is commonly double and out of line with the ring. There may be two and even three signet rings in one red corpuscle. The segmented state is rarely, if ever, seen in the peripheral blood, and produces only from eight to fifteen *merozoites.* Characteristic crescent-shaped bodies appear in the peripheral blood in about ten days after infection; these are the sexual forms (*gametocytes*) and occur in this species of Plasmodium only. The *macrogametocyte* or female form (Fig. 86-8a) shows the chromatin granules well concentrated in the mid region, while the *microgametocyte* or male form (Fig. 86-8b) has a more hyaline appearance. The macrogametocyte occurs also in an oval form (Fig. 86w) which has been looked upon (Schaudinn) as a parthenogenetic form which after long periods of latency might give rise by direct sporulation to new merozoites and thus account for the recurrence of malaria in persons who have not been newly infected. This theoretical cycle, generally believed to be erroneous, is illustrated in Fig. 86, w, x, y, z.

b. Plasmodium vivax Grassi and Feletti (*Hæmamœba vivax* Grassi and Feletti) is the cause of tertian fever or benign tertian malaria of temperate climates, occurs also abundantly in the tropics and subtropics, with regularly recurrent paroxysms every 48 hours. In these parasites the pigment granules are very fine and are distributed throughout the red corpuscles as Schüffner's dots. The parasitized corpuscles are distinctly enlarged and are quite pale. The signet ring is large and conspicuous and the dot is in line with the ring and rarely double. The parasites are bizarre in form. There are no crescents in this species, and the gametocytes are not easily distinguishable from the asexual parasites, except for their more regular form and denser pigmentation. The number of elements in the sporulating or segmented stage commonly seen in the peripheral blood is larger than in the former (12 to 20) and their arrangement is irregular. Sporulation occurs regularly every 48 hours.

c. Plasmodium malariæ Laveran (*Laverania malariæ* Grassi and Feletti, *Hæmamœba malariæ* Grassi and Feletti) is the cause of quartan fever, with recurrent paroxysms every 72 hours. This form of malaria is comparatively rare, and coincides in distribution with estivo-autumnal fever. The pigment is coarse and generally occurs in marginal streaks or in bands. The parasitized corpuscles are usually normal in size, and the parasite is small and more or less oval in shape. The gametocytes are rarely seen. The segmenting stage gives rise to the typical "daisy" form, each sporulated body radiating from the center. The number of bodies varies from 6 to 12, oftenest 8 (Deaderick). Sporulation occurs every 72 hours.

d. Plasmodium falciparum quotidianum Craig is believed to be the causative organism of quotidian malaria, with paroxysms recurring every 24 hours. The quotidian form of malaria occurs in practically

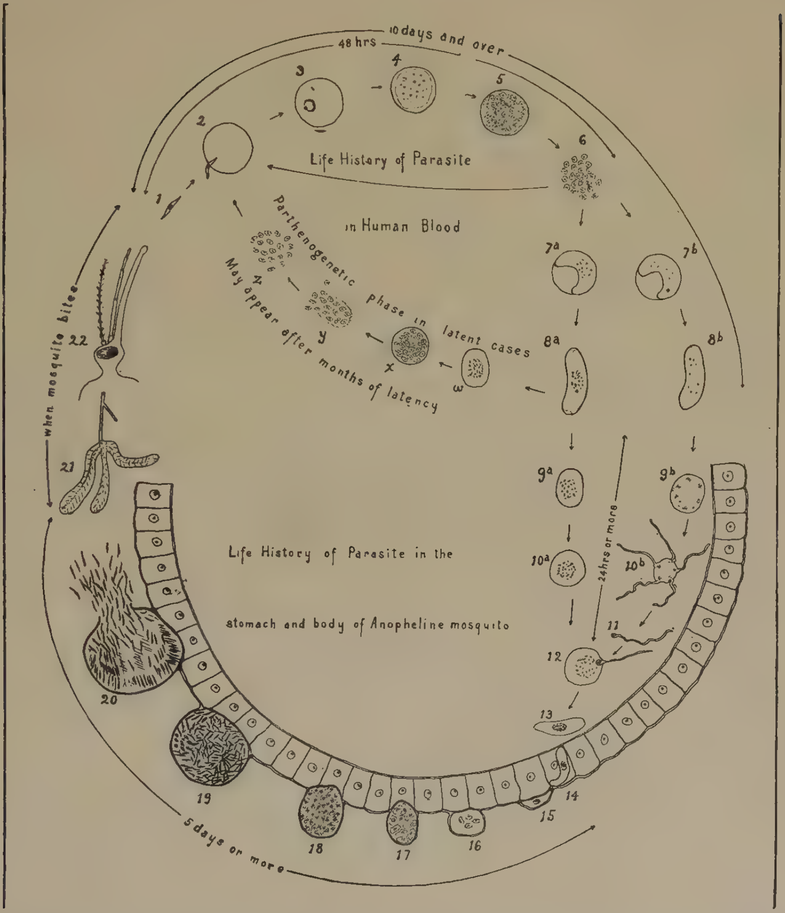

Fig. 86.—Diagram to show life history of parasite (*Plasmodium falciparum*) of estivo-autumnal malaria. 1-6, asexual or schizogonic cycle in human blood, requiring 48 hours to complete (72 hours in quartan); 1, represents a vermicule or sporozoite, either in salivary gland of mosquito or newly injected into human circulation; 2, represents a red blood corpuscle about to be parasitized by a sporozoite; 3, shows a young parasite in signet ring form; 4, fully grown parasite with dividing nucleus; 5, shows parasite sporulated, but still intracorpuscular; 6, sporulation, each body a merozoite ready to enter a new corpuscle; some are sexual and may develop into gametes; *7a,* female gametocyte, still intracorpuscular; *7b,* male gametocyte, also intracorpuscular; *8a,* free female crescent; *8b,* male gametocyte or hyaline crescent (crescents do not ordinarily appear in the blood until ten days or more after infection); w, x, y, z represents theoretical parthenogenetic cycle; 9-20 illustrates the sporogonic or sexual cycle of the parasite within the body of a female Anopheline mosquito, requiring six to ten days and over to complete; *9a, 9b,* female and male gametocytes in stomach cavity of mosquito; *10a,* female gamete (macrogamete); *10b,* exflagellated male gametocyte; 11, deflagellated male gamete (microgamete); 12, fertilization; (9-13 requires about 24 hours.) 13, oökinete or zygote ready to penetrate stomach; 14, oökinete burrowing through stomach wall; 15, oökinete outside of stomach wall and inside peritoneal lining, forming characteristic cyst, growing progressively larger. (16-19) in which the parasite sporulates, forming the sporozoites; 20 shows sporozoites (vermicules) escaping from cyst and migrating forward to salivary glands (21); (14-20 requires five days or more.) 21, salivary glands of female mosquito; 22, head of female Anopheles. (Original, with suggestions from Grassi and Schaudinn in Mense's *Handbuch.*)

all parts in which estivo-autumnal fever occurs, and might result from multiple infection on the part of tertian parasites or the adventitious sporulation of the subtertian parasite, both of which occur and it may be pressing the matter too far to establish a separate subspecies on all too meager morphological ground. The parasite is said to resemble very closely *P. falciparum,* but the infected corpuscles are said to be considerably smaller than normal, and are usually brassy in appearance.

Life History of the Plasmodium.—The life history of the malaria Plasmodium involves two distinct cycles; first, the *asexual,* also known as the human cycle, cycle of Golgi or schizogonic cycle; and secondly, the *sexual,* also known as the mosquito cycle, cycle of Ross or sporogonic cycle. A third cycle, purely theoretical and believed to be erroneous, attempts to explain the recurrence of malaria after longer periods of latency, is known as the *parthenogenetic* or virgin cycle (Fig. 86, w, x, y, z).

The *asexual cycle* (Fig. 86, 1-6), passed within the blood of the human being, begins with the introduction of spindle-shaped *sporozoites* injected into the circulation with the bite of the Anopheles mosquito. Each sporozoite not destroyed by leucocytes at once enters a red cell, where it (now known as a *trophozoite*) quickly goes into the *signet ring* stage (Fig. 86-3), growing rapidly until the corpuscle is more or less filled depending upon the species of parasite, and is then known as a *merocyte.* The full-grown merocyte (also known as a *schizont*) now divides into a larger or smaller number of bodies (also depending upon the species) which are then liberated, being now free in the plasma and are known as *merozoites.* The time required for this sporulation is from 24 to 72 hours according to the species. Each merozoite unless destroyed by leucocytes now attaches itself to and gradually enters another red cell and again the cycle repeats until the infection is great enough to produce a paroxysm, i.e., in from 6 to 12 days, commonly about 10 days.

The great majority of the merozoites are asexual, but some of them are potential males and females, which require a longer time, probably not less than 10 days, to develop to their full growth, then known as *gametocytes.* In *Plasmodium vivax,* the sexual forms are not easily recognized; however, the following characters are useful: "(1) their larger size, (2) more abundant pigment, (3) there is usually only one fairly large chromatin mass, whereas in an asexual form of nearly equal size the chromatin has already begun to divide into several portions (segmenting stage)" (Stephens and Christophers). In *P. falciparum* the sexual individuals are in the form of crescents. The female crescent (macrogametocyte) has the pigment collected at the center, while the male crescent (microgametocyte) has the pigment scattered throughout and is known as a hyaline crescent.

With complete development of the gametocytes all is ready for the

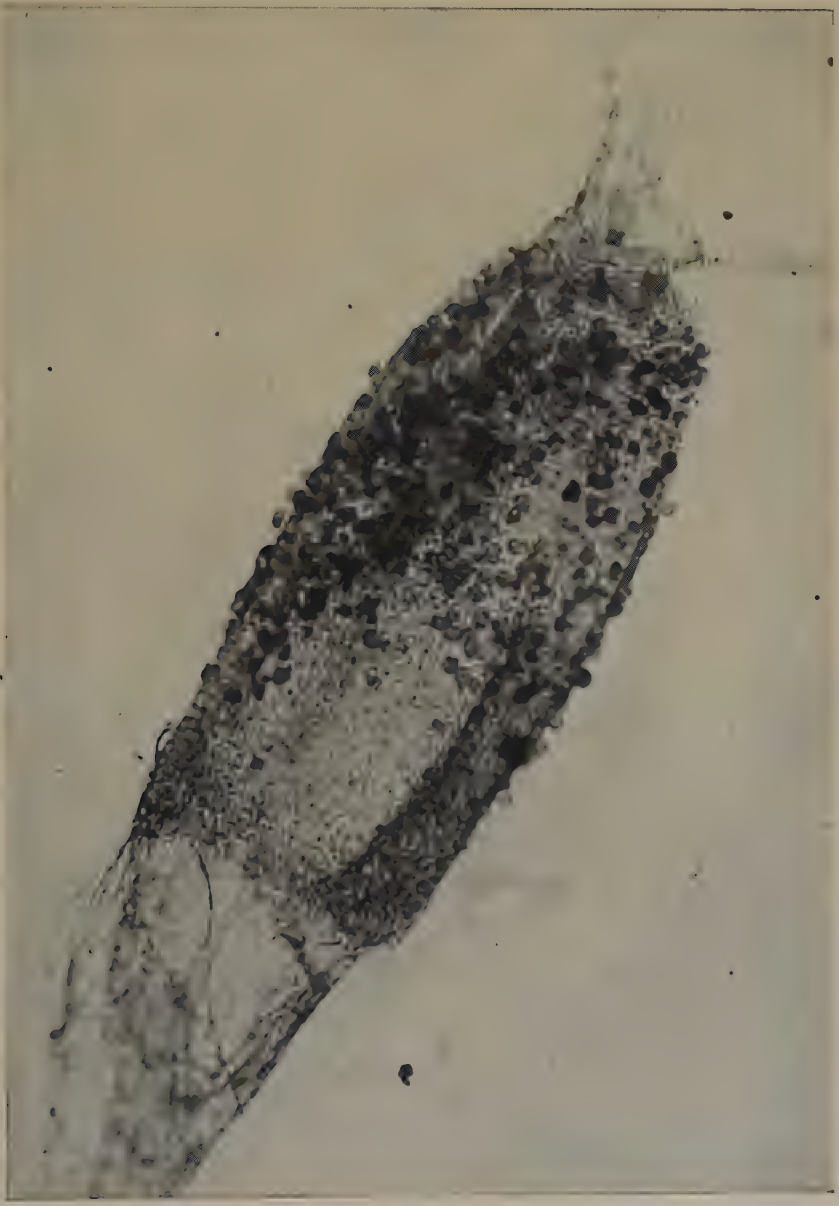

FIG. 87.—Shows stomach of female anopheles mosquito with numerous plasmodial cysts.

next cycle (the sexual) which can only be undergone within the body of certain anopheline mosquitoes. In the meantime the asexual cycle is repeated until senescence of the parasite occurs or unless quinin is taken to destroy them. The gametocytes are not easily destroyed, persisting in the body for long periods of time, and may, under certain conditions, result in relapses, without reinfection by mosquitoes, which relapses are said to be traceable to a parthenogenetic cycle of the female gametocyte (Fig. 86, w, x, y, z). But for this phenomenon, which may, of course, fail to occur, a person eventually becomes rid of malaria, provided he avoids reinfection by mosquitoes, because of the senescence which naturally results from continued sporulation without sexual intervention or rejuvenation in the mosquito. This is aided by *phagocytosis.* It is believed that this senescence or eventual dying off of the non-sexual forms is due to the toxin produced by the organisms reacting upon themselves.

Hence it becomes clear that the sexual cycle is necessary to the life of the species. It is a well-known fact that the male gametocyte extrudes flagella when malarial blood is exposed to the air, as when in contact with a glass slide. The parasites when thus taken from their normal habitat invariably die within a few minutes, unless a special medium is employed; e.g., that devised by Bass and Johns[1] in which the asexual cycle may be observed outside of the human body.

Sexual development, the cycle of Ross (Fig. 86-9-21) has only been observed in certain female anopheline mosquitoes; in the stomach of which flagellation of the male gametocyte takes place. After a peripheral arrangement of the chromatin (in clumps corresponding to the number of flagella) there are extruded from three to six long slender filaments (flagella), each of which breaks loose from the parent body (exflagellation), forming the male *gamete* (*microgamete*) corresponding in function to the spermatozoon of higher animals. The female gametocyte, now known as the macrogamete, having been taken into the stomach of the mosquito with the microgametocytes in the act of sucking blood, also undergoes certain changes (maturation) becoming rounded or oval in form with the chromatin mass centrally located. In this condition and still in the stomach of the mosquito, the microgamete conjugates with the macrogamete, producing the *oökinete,* vermicule or zygote in which stage the epithelium of the stomach is penetrated and a position is taken up just beneath the peritoneal membrane. In this position the parasite grows enormously, forming a cyst (*oöcyst*) (Fig. 87) in which many nuclei appear in from 4 to 5 days. These tiny nucleated bodies give rise to hundreds of spindle-shaped organisms (*sporozoites*) which are in from 24 to 48 hours more shed into the body cavity of the mosquito (Fig. 88). The majority of the sporozoites eventually collect in the salivary glands, remaining there until the mosquito bites again, when many of them may be injected with the saliva into the wound. The time required for the completion of the sexual cycle varies from 7 to 10 days under favorable conditions. Once infected the mosquito probably remains infected for the rest of its life.

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[1] Bass, C. C., and Johns, F. M., 1912. The cultivation of malarial plasmodia *in vitro.* Journ. Exp. Med., Oct. 1, 1912, p. 567.

Anopheles Infectivity Experiments.—Contrary to a widespread belief, not all anophelines are able to transmit malaria. Hindle[1] points out that, "the first instance of an *Anopheles* being shown not to transmit malaria was in the case of the common Indian species *A.* (*Myzomyia*) *rossi.* This species is found quite commonly in very large numbers associated with every degree of prevalence of malaria, but it has not been shown to act as a transmitting agent (in India) under natural conditions, though it can be infected experimentally." The writer has seen enormous numbers of *A. pseudopunctipennis* in certain parts of California under presumably favorable climatic and population conditions and yet malaria was practically absent while in other

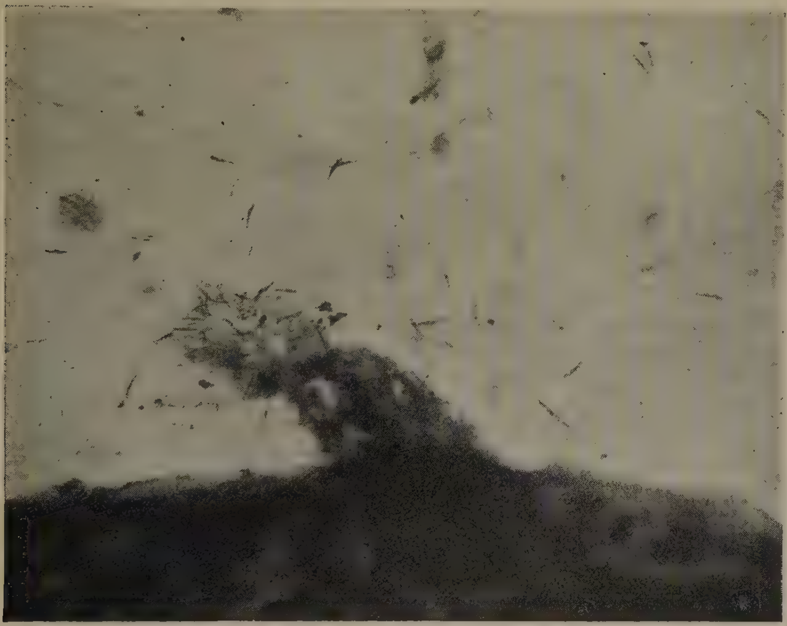

Fig. 88.—Shows a bursting plasmodial cyst on stomach of mosquito. Spindle shaped sporozoites being liberated. (Greatly magnified.)

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[1] Hindle, Edward, 1914. Flies in relation to disease,—blood-sucking flies. Cambridge University Press, xv + 398 pp.

near-by localities where in addition to the above either *A. punctipennis* or *A. maculipennis*, or both, were present even in comparatively small numbers the malaria rate was fairly high. Furthermore, the several species of *Anopheles* do not all equally favor the several species of malaria plasmodia, thus *A. maculipennis* and *A. quadrimaculatus* are known to be carriers of three species of plasmodia (Beyer, *et al.*,[1] Thayer,[2] King,[3] while *A. punctipennis* is a strong carrier of the tertian parasite and a very weak one (probably negligible) for the estivo-autumnal parasite (Darling[4]).

The following experiment made by Mitzmain[5] illustrates the manner of procedure in infectivity experiments:

"For the purpose of this study, 338 specimens of *Anopheles punctipennis* were collected in barns and stables at Talladega Springs, Ala., January 7-15, 1916, and transported in cages to the New Orleans laboratory. (The improbability of infection of 'wild' Anopheles mosquitoes in this section and during this season seemed to warrant their use in conducting these experiments.) The feeble and dead mosquitoes were withdrawn upon arrival and either used for smear preparations or dissected in the usual manner for the purpose of examination for malarial parasites. One hundred and sixty-six mosquitoes were separately suspended in a drop of saline dissecting medium on a slide and the abdominal and thoracic contents were teased out. Smears were then made from each and stained over night in a weak Giemsa stain.

"One hundred and twenty-six specimens were fed on a healthy person at least once each, then dissected during a period of 20 days. The results in all instances failed to indicate the presence of any plasmodial infection.

"An untreated patient suffering from tertian malarial fever volunteered for the purpose of furnishing the parasites required in this experiment. During the interval of awaiting gametocyte development (January 17-February 6) several generations of complete schizogony were observed to occur in the patient's blood. However, sporogony was unduly inhibited up to January 29, too few gametocytes being present to assure infectivity of the definitive hosts. Finally, sufficient numbers of sexual forms matured during January 29 to February 6, at the termination of which period (February 6 and 7) mosquitoes were applied to the patient.

"The paucity of sexual parasites in the blood of the donor may be appreciated from the counts made in a thick film and a thin film prepared

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[1] Beyer, G. E., Pothier, O. L., Courtet, M., and Lemann, J., 1901-02, I., Bionomics,—Experimental Investigation with *Bacillus sanerelli* and Experimental Investigation with Malaria. New Orleans Med. and Surg. Journ., Vol. 54, pp. 419-480.

[2] Thayer, W. S., 1900. On recent advances in our knowledge concerning the Etiology of malarial fevers. Phila. Med. Journ., Vol. 5, pp. 1046-1048.

[3] King, W. V., 1916. Experiments on the development of malaria parasites in three American species of Anopheles. Journ. Exp. Med., Vol. 33, No. 6, pp. 703-716.

[4] Darling, S. T., 1910. Studies in relation to malaria. Isthmian Canal Commission Report. U. S. Government Printer, Washington, D. C.

[5] Mitzmain, M. B., 1916. Tertian malarial fever,—transmission experiments with *Anopheles punctipennis*. U. S. Public Health Service. Reprint No. 337 from U. S. Public Health Reports, May 12, 1916, pp. 1172-1177.

February 7. In the two preparations 1,231 leucocytes were counted and the matured gametocytes encountered numbered two, an average of one gametocyte to 616 leucocytes. In addition to these there were observed in the two blood specimens, 48 half-grown gametocytes and 5 ranging in size from three-fourths to nearly full-grown forms. At the time of these examinations the patient had been started on a course of quinine treatment.

"Forty specimens of *Anopheles punctipennis* were applied to the tertian donor in two lots on February 6 and 7, 1916; 20 of these died within five days and were dissected. Oökinets were observed in at least eight of these, from which smear preparations were made. Twenty mosquitoes were dissected during a developmental period ranging from 6 to 25 days.

"During the course of the experiment raisins and water were furnished as food, while the mosquitoes were subjected, prior to the 10th day, to an incubator temperature of 25.5°-26° C. Thirteen of this lot of 30 (equal to 32.5 per cent) became infected.

"In order to eliminate any possibility of doubt as to the nature the parasites harbored by the mosquitoes and as a further check on the infectivity of *Anopheles punctipennis,* three healthy persons volunteered to permit biting of these mosquitoes. Four specimens were selected for the purpose, namely, Nos. 18, 23, 24 and 25. The first volunteer (H. E. H.) was bitten February 17 by all four of the mosquitoes applied. At this time the mosquitoes had been infected 10 days. In this feeding, the mosquitoes were not permitted to engorge themselves but were applied a sufficient length of time to convince the observer and the host that blood was being withdrawn. Directly after the biting, six very distinct moderate-sized macules developed on the arm at the site of application. Nine days elapsed before the volunteer experienced prodromal symptoms of any kind. The first paroxysm was observed 14 days after the biting and parasites of *Plasmodium vivax* were found in the blood of H. E. H. on March 3 and March. 4.

"H. E. H. was employed previously in feeding mosquitoes which had been given the opportunity of becoming infected in two experiments from subtertian crescent carriers. More than 200 specimens of *Anopheles punctipennis* had been used in an attempt to transmit subtertian infection, with negative results. The volunteer, H. E. H., remained healthy throughout this test and subsequently for four months prior to the tertian transmission experiment. In the tertian infection the disease took its usual course and prompt recovery followed the use of therapeutic doses of quinine.

"Two of the mosquitoes, namely, Nos. 23 and 24, were induced to bite the second volunteer, Dr. H. A. T., February 18. These were observed to bite vigorously to a point of repletion. The mosquitoes at this time had been infected for a period of 11 days. After an incubation period of 14 days, Dr. H. A. T. experienced a distinct paroxysm; also on the same day parasites of tertian malaria (*Plasmodium vivax*) were found in his blood.

"A third volunteer, Dr. R. C. D., was bitten February 21 by mosquitoes, Nos. 24 and 25, 14 days after they had received an opportunity to become infected. The two specimens were applied to the arm so that they did not become engorged (interrupted feeding); the labia of both were observed to be inserted to the extreme before the mouths were withdrawn. Each bite required 40 seconds of time, resulting in distinct macules at the point of inoculation.

"An incubation period of 14 days followed in this case, with prodromata and the usual symptoms of chill followed by fever. A slight paroxysm was experienced on March 4, and parasites were observed March 5. Distinct tertian rings (*P. vivax*) were demonstrated in the blood of the volunteer in two specimens examined at five-hour intervals on the second day after onset."

Infective Species.—Experimental evidence shown in many different publications has been advanced to prove that numerous species of anopheline mosquitoes can carry malaria, and the following list is only intended to suggest the extensive character of such observations and is not intended to be complete. All species of malaria plasmodia are carried by the following:—*Anopheles maculipennis* Meig. (Europe and parts of the U. S.), *A. quadrimaculatus* Say (U. S.), *A. hyrcanus* Pall. = *A. sinensis* Wied. (India, China, Malay), *A. culicifacies* Giles (India), *A. funesta* Giles (Tropical Africa), *A. costalis* Loew (Tropical Africa). Both estivo-autumnal and tertian parasites are carried by *A. albimanus* Wied. (Central and So. America), *A. crucians* Wied. (U. S.), *A. punctipennis* Say (U. S.), *A. kochii* Don. (Sumatra). Although further evidence may prove otherwise the following species are proved to be carriers of only the estivo-autumnal parasite, viz.:—*A. albirostris* Theo. (So. China and Malay), *A. barbirostris* Van der W. (India, China, Malay), *A. formosænsis* Tsuzu. (Formosa), *A. ludlowi* Theo. (Sumatra), *A. maculatus* Theo. (India), *A. maculipalpis* var *indiensis* Theo. (India), *A. turkhudi* Giles (India), *A. tarsimaculatus* Goeld. (So. and Central America), *A. annulipes* Walk (Australia).

Number of Persons Infected by One Mosquito.—It is important to know if an Anopheles once infected can infect more than one person without again feeding on infective blood. For example, country-school privies as the writer has often observed may be literally infested with Anopheles mosquitoes and the opportunity is given many of them to bite different persons in quick succession. In a most instructive series of experiments conducted by Mitzmain[1] he reports that one mosquito proved to be the sole infecting agent in three cases. Mitzmain used *Anopheles punctipennis* with *Plasmodium vivax*. He also demonstrated in eleven experiments that short exposure to bites was sufficient to cause successful transmission of the disease.

Effect of Temperature on Parasites.—In spite of the fact that apparently all conditions are favorable, there being numerous anopheline carriers together with ample human population with sufficient carriers of plasmodial gametocytes, yet active malaria may be largely or wholly absent in particular localities. An analysis of conditions will usually reveal the fact that the average temperature is low due to normally cool nights although the days may be fairly warm, or because of prevalent cool fogs. It is generally pointed out that malaria gametocytes cannot successfully develop within the body of the mosquito host below a temperature of about 15° C. It is nevertheless a matter of interest to know that King[1] observed the survival of the parasite of tertian malaria in the mosquito host (*Anopheles quadrimaculatus*) at a temperature of 30° F. for a period of 2 days, at 31° F. for 4 days, and at 46° F. for 17 days, and the parasite of estivo-autumnal malaria survived a temperature of 35° F. for 24 hours.

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[1] Mitzmain, M. B., 1916. An attempt to determine the number of persons one mosquito can infect with malaria. U. S. Public Health Reports, Vol. 31, No. 35, pp. 2325-2335.

In addition to the retardation and eventual complete inhibition of plasmodial development, temperature also plays an important rôle in the biology of anophelines, although the insect is able to endure much lower temperatures and is able to go into hibernation during the winters in cold climates. Hibernation of the anopheline host presents the problem of the overwintering of the parasite. Mitzmain[2] again comes forward with an excellent discussion of the question, "Is mosquito or man the winter carrier of malaria organisms?" He reaches the conclusions that

> "hibernating anopheles, collected in the region investigated (northwestern Mississippi) did not harbor parasites of malaria. This was determined after an examination of 2,122 dissected anophelines, of which 1,211 specimens were examined before May 15, 1915. Among the remaining 911 specimens, serving as a malaria indicator for the spring season, 3 mosquitoes, between May 15 and May 26, were definitely shown to contain oöcysts, indistinguishable from those seen in mosquitoes experimentally infected with human malaria.
>
> "In the investigation of man as the responsible winter carrier, 1,184 persons, residing on the plantations selected, were examined for malaria parasites. Four hundred and ninety-two infections were identified microscopically; 317 cases were of the subtertian type, 8 were mixed infections, and the remainder were of the simple tertian type, with the exception of one quartan case.
>
> "In the consideration of these infections an important fact stands out: *nearly one-fourth (24.8 per cent) of the human carriers harbored gametocytes.*
>
> "It was proved that from a group of 103 persons, examined in March, 1915, 8 of the 15 gametocyte carriers identified, were similarly infected during the preceding fall.
>
> "The incrimination of man as the sole winter carrier is emphasized by the fact that 3 malaria-infected *Anopheles quadrimaculatus* were found in the homes of these gametocyte carriers during May 15 to May 26, previous to which time 1,180 speciments of *Anopheles* from this source were found to be negative."

Quinin Prophylaxis and Treatment.—It has already been suggested in this and the preceding chapter that quinin holds an important place in the campaign against malaria. If a spring campaign against mosquitoes is planned, it is the part of wisdom to search out by blood examination all plasmodial carriers and put them through a rigorous course of quinin treatment during the autumn and winter to prevent spring and early summer relapses which are not only sure to discredit mosquito control, no matter how thorough, but the possibility of mosquitoes to become infected from such local population is also practically reduced to nil.

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[1] King, W. V., 1917. The effect of cold upon malaria parasites in the mosquito host. Journ. Exp. Med., Vol. XXV, No. 3, pp. 495-498.

[2] Mitzmain, M. B., 1916. Is mosquito or man the winter carrier of malaria organisms? U. S. Public Health Service, Public Health Bull. No. 84, 32 pp.

At the beginning of the Anderson (Calif.) malaria campaign[1] an index was taken during June (1919) with the following results:

Preliminary Malarial Index, June, 1919

	Blood smears			*Histories*			*Number taking quinin*
	—	+	%	—	+	%	%
Totals examined......	90	29	25.2	33	86	72.2	53
Adults	62	16	20.6	29	50	64.1	40
10–15 years...........	18	10	35.7	3	25	80.3	10
Under 10 years......	10	3	23.0	2	11	84.6	3

Positive cases were given quinin, 10 grains three times a day for seven days, then 20 grains every evening for seven days and 10 grains daily for ten weeks. At the close of the work 76 patients who had come under observation and treatment were again examined. Sixty-four, or 84.2 per cent were negative and had had no recurrence of clinical symptoms. Successful cases averaged slightly better than 20 grains of quinin per day throughout the first week of treatment, while the failures took slightly over 9. Tertian malaria responded much more readily to treatment than estivo-autumnal; every case of the former that came under observation being apparently cured. Cured cases of estivo-autumnal averaged 12 grains per day over 41 days, while the tertian averaged 11 grains per day over 39 days. Failures (all estivo-autumnal) averaged 5 grains per day over 31 days.

In localities where it is not practicable to control mosquitoes, and that may be the case in rare instances, the use of quinin in small doses may be practiced in order to prevent malaria. Carter[2] states that "it should be taken in doses of from 5 to 7 grains per day by grown people, 2 to 3 grains by children—less if small—during the malarial season, say June to November. Somewhat smaller doses will be efficient in places where the malaria is not bad. . . . In these doses it does no injury of any kind to those taking it."

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[1] Freeborn, S. B., 1920. Malaria control,—a report of demonstration studies at Anderson, California. Calif. State Bd. of Health Mo. Bull., Vol. 15, No. 9, pp. 279-288.

[2] Carter, H. R., 1918. Prophylaxis of malaria, immunization by quinine. U. S. Public Health Service. Reprint No. 454 (Public Health Reports, Vol. 29, No. 13, pp. 741-749).

Concerning the comparative cost of mosquito control and treatment of carriers, the following comparisons from the Rockefeller Foundation "Review for 1918" are of interest. In Hamburg, Arkansas, a reduction of 97.4 per cent was secured by mosquito control at a cost of $1.45 per capita in 1917; for 1918 it was only 44 cents. Neither this cost nor the next includes the overhead expenses of supervision by representatives of the Board. In Sunflower County, Mississippi, a demonstration was undertaken by the Foundation's International Health Board aimed at *curing* the carriers. A control of 80 per cent was secured in the rural area at an initial per capita cost of $1.08. This would appear to throw favorable light on this method of malaria control, namely, treatment of carriers.

It should be remembered, however, that the administration of quinin requires individual treatment and that strict supervision of a given population is difficult. Where large sums of money are necessary for carrying out a quinin program, it is well to consider first the possibility of correcting drainage defects and controlling the mosquito.

B. Yellow Fever

Yellow Fever.—Yellow fever, also known as Yellow Jack, Bilious remittent fever, Pestis Americana, and Fiebre Amarilla, is characterized by an abrupt primary rise of temperature, of comparatively short duration followed by a remission or intermission and then a second febrile paroxysm lasting much longer than the first, accompanied by albuminaria, bleeding of the gums and often jaundice. The disease is endemic in certain portions of Central America (Guatemala, Nicaragua and Costa Rica) and South America (Ecuador, Spanish Honduras, Venezuela) and the west coast of Africa. Epidemics of great magnitude have occurred in the southern United States, and Cuba was terribly punished by the disease for many years.

Yellow Fever Mosquito Borne.—Although Dr. Carlos Finlay of Havana had quite early (1881) advanced a mosquito transmission theory and had carried on what we now know to have been incriminating experiments with non-immunes, his theory was discredited until renewed interest in the same was given it by the work of the United States Army Yellow Fever Commission headed by Major Walter Reed in 1900. Reed[1] and his colleagues made a pre-report in which they state:

> "Since we here, for the first time, record a case in which a typical attack of yellow fever has followed the bite of an infected mosquito, within the usual period of incubation of the disease, and in which other sources

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[1] Reed, Walter, Carroll, James, Agramonte, A., and Lazear, Jesse W. The Etiology of Yellow Fever,—a preliminary note. Proc. of the Twenty-eighth Annual Meeting of the Amer. Public Health Assoc., Indianapolis, Ind., Oct. 22-26, 1900.

of infection can be excluded, we feel confident that the publication of these observations must excite renewed interest in the mosquito theory of the propagation of yellow fever, as first proposed by Finlay."

Senate Document No. 822 (Jan. 27, 1911) is concerned with yellow fever and contains a compilation of various publications by the Commission and others. In this document, McCaw gives the following account of the work of the Commission:

"In June, 1900, Major Reed was sent to Cuba as president of a board to study the infectious diseases of the country, but more especially yellow fever. Associated with him were Acting Asst. Surgs. James Carroll, Jesse W. Lazear, and A. Agramonte.

"At this time the American authorities in Cuba had for a year and a half endeavored to diminish the disease and mortality of the Cuban towns, by general sanitary work, but while the health of the population showed distinct improvement and the mortality had greatly diminished, yellow fever apparently had been entirely unaffected by these measures. In fact, owing to the large number of nonimmune foreigners, the disease was more frequent than usual in Habana and in Quemados near the camp of American troops, and many valuable lives of American officers and soldiers had been lost.

"Reed was convinced from the first that general sanitary measures alone would not check the disease but that its transmission was probably due to an insect.

"In June, July, and August, 1900, the commission gave their entire attention to the bacteriological study of the blood of yellow-fever patients and the post-mortem examinations of the organs of those dying with the disease. In 24 cases where the blood was repeatedly examined, as well as in 11 carefully studied autopsies, *Bacillus icteroides* was not discovered, nor was there any indication of the presence in the blood of a specific cause of the disease.

"Application was made to General Leonard Wood, the military governor of Cuba, for permission to conduct experiments on nonimmune persons, and a liberal sum of money requested for the purpose of rewarding volunteers who would submit themselves to experiment.

"It was indeed fortunate, that the military governor of Cuba was a man who by his breadth of mind and special scientific training could readily appreciate the arguments of Major Reed as to the value of the proposed work.

"Money and full authority to proceed were promptly granted, and to the everlasting glory of the American soldier, volunteers from the Army offered themselves for experiment in plenty and with the utmost fearlessness.

"Before the arrangements were entirely completed, Dr. Carroll, a member of the commission, allowed himself to be bitten by a mosquito that 12 days previously had filled itself with the blood of a yellow-fever patient. He suffered from a very severe attack, and his was the first experimental case. Dr. Lazear also experimented on himself at the same time, but was not infected. Some days later, while in the yellow-fever ward, he was bitten by a mosquito and noted the fact carefully. He acquired the disease in its most terrible form and died a martyr to science and a true hero.

"No other fatality occurred among the brave men who, in the course of the experiments, willingly exposed themselves to the infection of the dreaded disease.

"A camp was especially constructed for the experiments about 4 miles from Habana, christened Camp Lazear in honor of the dead comrade. The inmates of the camp were put into most rigid quarantine and ample time was allowed to eliminate any possibility of the disease being brought in from Habana.

"The personnel consisted of three nurses and nine nonimmunes, all in the military service, and included two physicians.

"From time to time Spanish immigrants, newly arrived, were brought in directly from the immigrant station; a person not known to be immune was not allowed to leave camp, or if he did was forbidden to return.

"The most complete record was kept of the health of every man to be experimented upon, thus eliminating the possibility of any other disease than yellow fever complicating the case.

"The mosquitoes used were specially bred from the eggs and kept in a building screened by wire netting. When an insect was wanted for an experiment it was taken into a yellow-fever hospital and allowed to fill itself with the blood of a patient; afterwards at varying intervals from the time of this meal of blood it was purposely applied to nonimmunes in camp.

"In December, 5 cases of the disease were developed as the result of such applications; in January, 3, and in February, 2, making in all 10, exclusive of the cases of Drs. Carroll and Lazear. Immediately upon the appearance of the first recognized symptoms of the disease, in any one of these experimental cases, the patient was taken from Camp Lazear to a yellow-fever hospital, 1 mile distant. Every person in camp was rigidly protected from accidental mosquito bites, and not in a single instance did yellow fever develop in the camp, except at the will of the experimenters.

"The experiments were conducted at a season when there was the least chance of naturally acquiring the disease, and the mosquitoes used were kept active by maintaining them at a summer temperature.

"A completely mosquito-proof building was divided into two compartments by a wire-screen partition; infected insects were liberated on one side only. A brave nonimmune entered and remained long enough to allow himself to be bitten several times. He was attacked by yellow fever, while two susceptible men in the other compartment did not acquire the disease, although sleeping there 13 nights. This demonstrates in the simplest and most certain manner that the infectiousness of the building was due only to the presence of the insects.

"Every attempt was made to infect individuals by means of bedding, clothes, and other articles that had been used and soiled by patients suffering with virulent yellow fever.

"Volunteers slept in the room with and handled the most filthy articles for 20 nights, but not a symptom of yellow fever was noted among them, nor was their health in the slightest degree affected. Nevertheless they were not immune to the disease, for some of them were afterwards purposely infected by mosquito bites. This experiment indicates at once the uselessness of destroying valuable property for fear of infection. Had the people of the United States known this one fact 100 years ago, an enormous amount of money would have been saved to householders.

"Besides the experimental cases caused by mosquito bite, four nonimmunes were infected by injecting blood drawn directly from the veins of yellow-fever patients in the first two days of the disease, thus demonstrating the presence of an infectious agent in the blood at this early period of the attack.

"Even the blood serum of a patient, passed through a bacteria-proof filter, was found to be capable of causing yellow fever in another person."

The conclusions reached by the Commission follow:

"1. The mosquito (*C. fasciatus-Aëdes aegypti*) serves as the intermediate host for the parasite of yellow fever.

"2. Yellow fever is transmitted to the nonimmune individual by means of the bite of the mosquito that has previously fed on the blood of those sick with this disease.

"3. An interval of about 12 days or more after contamination appears to be necessary before the mosquito is capable of conveying the infection.

"4. The bite of the mosquito at an earlier period after contamination does not appear to confer any immunity against a subsequent attack.

"5. Yellow fever can also be experimentally produced by the subcutaneous injection of blood taken from the general circulation during the first and second days of this disease.

"6. An attack of yellow fever, produced by the bite of the mosquito, confers immunity against the subsequent injection of the blood of an individual suffering from the nonexperimental form of this disease.

"7. The period of incubation in 13 cases of experimental yellow fever has varied from 41 hours to 5 days and 17 hours.

"8. Yellow fever is not conveyed by fomites, and hence disinfection of articles of clothing, bedding, or merchandise, supposedly contaminated by contact with those sick with this disease, is unnecessary.

"9. A house may be said to be infected with yellow fever only when there are present within its walls contaminated mosquitoes capable of conveying the parasite of this disease.

"10. The spread of yellow fever can be most effectually controlled by measures directed to the destruction of mosquitoes and the protection of the sick against the bites of these insects.

"11. While the mode of propagation of yellow fever has now been definitely determined, the specific cause of this disease remains to be discovered."

Etiology.—The search for the causal agent of yellow fever has been carried on most assiduously for many years and discoveries have been announced from time to time. Thus Sanarelli in 1897 declared the organism to be *Bacillus icteroides*, amply disproved by the U. S. Yellow Fever Commission in 1900. Seidelin in 1909 described *Paraplasma flavigenum* (belonging to the protozoan family Babesiidæ) as the causal agent, but in 1919 Noguchi (*loc. cit.*) advanced most conclusive evidence that the causative organism of yellow fever is *Leptospira icteroides*.

The virus is believed to be present in the circulation only during the first three days of the disease; blood in the infective stage quickly loses its virulence on exposure to air and becomes non-virulent at a temperature of 55° C. within five minutes. The extreme sensitiveness to heat of both the mosquito carrier (*Aëdes ægypti* = *Stegomyia calo-*

pus) and the causal agent explains the restricted geographical distribution of yellow fever. Thus the virus cannot develop within the body of the mosquito at a temperature below 21° C. to 20° C.

The work of certain French investigators Marchoux and Simond point to the possibility of virus transmission through the mosquito egg to the offspring, which does not occur in malaria transmission and would make mosquito control in anti-yellow-fever campaigns a matter of paramount importance. As in malaria the mosquito apparently remains infective once it has become so.

C. Filariasis

Filariasis.—Filariasis is a condition characterized by the presence of nematode worms of the family Filariidæ in the circulatory and lymphatic system of man and beast and may or may not result in injurious effects. The microscopic worms present in the circulation are young forms which mature in certain lymph glands and vessels where their presence may result in occlusion and consequently a condition of varicose dilation or enlargement of the affected parts such as scrotum, vulva, legs and breast (Fig. 89). These parts may become enormously enlarged and this condition is known as *Elephantiasis*. However, it is a matter of common observation that filariæ are not usually encountered in such cases and by certain authors it is believed that elephantiasis is at least not the direct result of filariasis.

Filariasis occurs in many parts of the tropical and subtropical world, being extremely common in the South Sea Islands (Samoa and Tahiti). In the United States there is filariasis in Charleston, S. C., where it has been endemic for many years, having been imported according to Francis[1] by a shipload of slaves from a heavy focus of infection in Africa.

The Parasite.—Although there are several blood-inhabiting worms belonging to the family Filariidæ, only one species seems to be of any great pathological importance, namely *Microfilaria bancrofti* Cobbold (= *Filaria sanguinis hominis* Lewis), a tropical and subtropical species.

Microfilaria bancrofti, which is the larval form of *Filaria bancrofti*, inhabits the blood plasma, is a very slender worm, about the diameter of a red blood corpuscle and is about .3 mm. in length (Fig. 90). It is inclosed in a very delicate sheath inside of which the worm has some latitude of motion both forward and backward. It is known that this parasite maintains a very striking periodicity, being abundant in the peripheral circulation only at night, beginning with the early evening and lasting until early morning with the greatest abundance at midnight, at which time Manson reports that "it is no unusual

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[1] Francis, Edw., 1919. Filariasis in Southern United States. U. S. Public Health Service Bulletin No. 117, 36 pp.

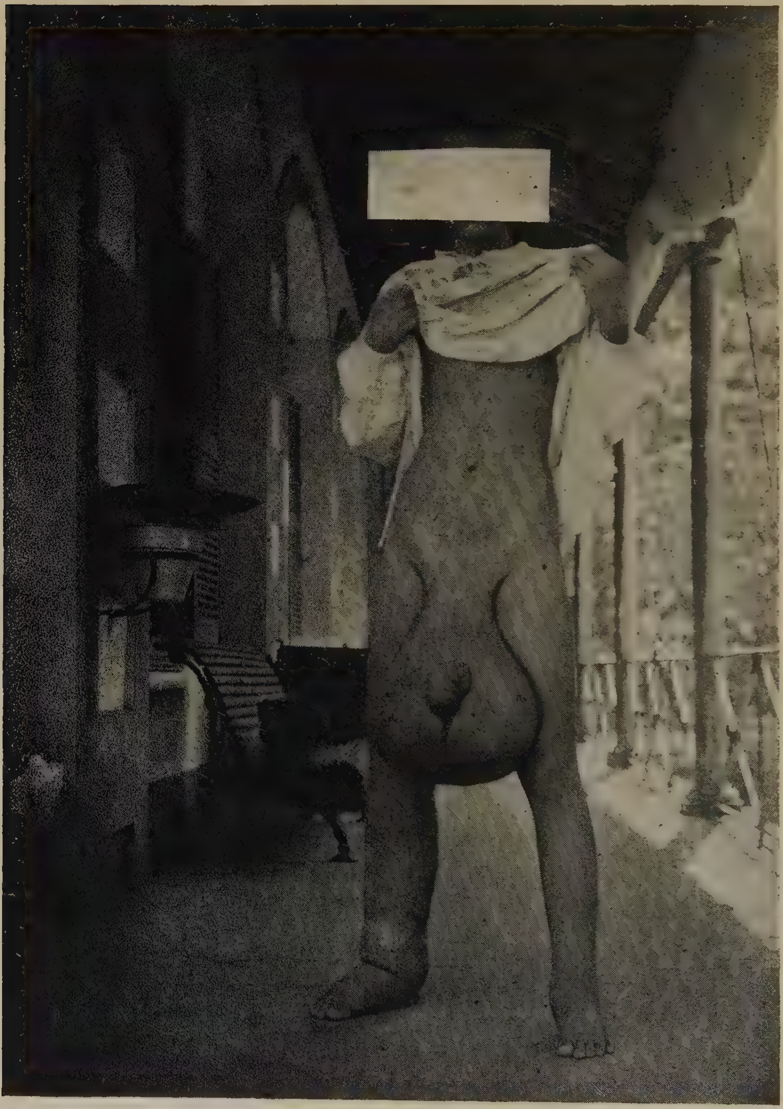

Fig. 89.—Advanced case of elephantiasis of scrotum and right leg and foot; left ankle and foot less affected.

thing to find as many as three hundred, or even six hundred in every drop of blood." During the day filariæ are found in the lungs and large visceral blood vessels.

The adult filariæ, which are slender hair-like worms, inhabit the lymphatic ducts. The female parasite measures from 85 to 90 mm. in length and the male about 40 mm. (Manson). The ovoviviparous females extrude myriads of larvæ into the blood vessels, occupying the lungs mainly during the day and the peripheral vessels by night.

The Mosquito's Rôle in Filariasis.—Manifestly the swarming of thousands upon thousands of microfilariæ in the peripheral blood at night offers the very best opportunity for passage into the body of nocturnal blood-sucking insects, of which the mosquito stands the best chance, owing to relative abundance and habits The Culicine mosquitoes for some reason seem to be the most important instruments of transmission, particularly *Culex* (*fatigans*) *quinquefasciatus* Say.

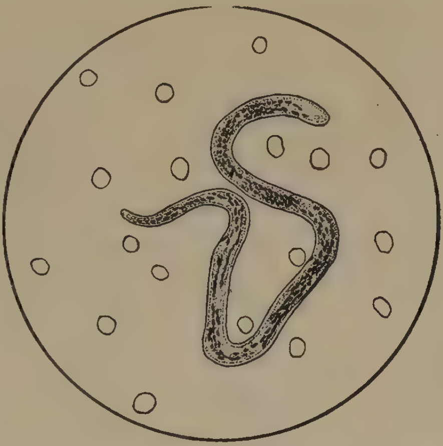

FIG. 90.—*Microfilaria bancrofti*, in human blood. × 333.

Once the microfilariæ are in the stomach of the mosquito these burst themselves free from their enclosing sheaths and proceed to migrate to the thoracic muscles, where a definite metamorphosis is undergone, resulting in a great increase in size, and the formation of a mouth and alimentary tract (Manson). This metamorphosis requires from 16 to 20 days, depending on the temperature as do other mosquito-borne parasites. From this position the worms work their way into the ventral portions of the head and the proboscis inside the labium. From this point they enter the wound produced when the mosquito pierces the skin of its victim. Apparently the filariæ burrow directly through the membranous portion of the labella at the point of attachment to the labium. From the peripheral system the nematodes soon find their way into the lymphatics where sexual maturity occurs.

Culex (*fatigans* Wied.) *quinquefasciatus* Say is one of the most abundant and widely distributed species of Culicine mosquitoes of the tropics and subtropics. It is a comparatively small species (about 5 mm.) and is uniformly brown, varying from light to dark, in color. On the thorax there are situated two narrow median indistinct longitudinal lines. Apparently any stagnant fresh water, from the clearest to the vilest, affords a good breeding place for *Culex quinquefasciatus.* Stagnant, filthy gutter water seems to be especially favorable.

The entire life history, from egg to imago, is completed in about ten days under optimum conditions.

The differences in the process of mosquito transmission in malaria and filariasis are pointed out by Francis (*loc. cit.*) as follows:

> "The *first* difference is that while in the case of malaria, and probably in yellow fever also, the parasite multiplies enormously in the mosquito, no multiplication of the filarial parasite whatever takes place in the mosquito; if the mosquito imbibes only one microfilaria from the blood of a filarial patient she can give back only one larva to the human subject.
>
> "The *second* difference in the process is that in filariasis every act or step of mosquito transmission is characterized by a small number of parasites; the number of microfilariæ imbibed by the mosquito is small and the number which successfully pass through the larval stage in her thoracic muscles and finally reach the proboscis to await the opportunity of an infecting bite is remarkably small; and the number of adults which reach a lymphatic gland of man is smaller still.
>
> "The *third* difference is that the filarial parasite as it leaves the mosquito's proboscis for man is of one sex or the other, and that multiplication must be deferred until a male and a female find lodgment within the *same* lymph gland of man and there grow and develop their genital organs preparatory to bringing about a fecundated adult female parent worm permanently located in that lymph gland and discharging her embryos into the blood stream. It is entirely possible that an individual might harbor a considerable number of adult parasites in his lymph glands and yet show no microfilariæ in his blood for the reason that those adults were so distributed among a number of lymph glands as to separate the sexes and thus preclude conjugation.
>
> "The *fourth* difference is found in the limited number of hours of maximum opportunity of infecting mosquitoes with filariæ; those hours being restricted to a few before midnight and a few after midnight.
>
> "The *fifth* difference in the process is that in the biting act which delivers the filarial larva back to man, the mosquito does not inject the larva into the blood stream of man but drops the larva on the free surface of the skin. The larva must then penetrate the intact skin and pass by the lymphatics to the nearest lymph gland.
>
> "*Sixth.* There are, moreover, certain additional difficulties attending the mosquito transmission of filariasis which weaken its efficiency. Probably half of the microfilariæ taken into a mosquito's stomach pass on into the hind gut and are lost instead of piercing the stomach wall and lodging in the thoracic muscles where the necessary larval changes must take place. Certainly a large proportion of the larvæ after they leave the thoracic muscles migrate backward into the abdomen and are lost, while others migrate into the legs or into the antennæ and palpi instead of into their necessary infecting position in the proboscis. The larvæ after liberation upon the skin are subject to being wiped off or washed off before they can penetrate the skin. The life of an infected mosquito is probably shortened by reason of harboring the worms."

Canine Filariasis.—Dogs in many parts of the world, particularly in China, Japan and Italy, are infected with a filarial worm known as *Filaria immitis* Leidy. The adult thread-like females measure from 25 to 30 cm. in length and the males from 12 to 18 cm., and are found mainly in the heart and larger blood vessels of the host. Here the embryos are liberated and swarm into the general circulation as in *Filaria bancrofti,* showing a similar nocturnal periodicity. The length of the embryos as found in the peripheral circulation is about 290 μ. These embryos are taken up by the mosquitoes, *Anopheles maculipennis, Aëdes œgypti* (= *A. calopus*), *Culex pipiens,* and probably other species, where certain changes take place and migrate to the proboscis as in *Filaria bancrofti.* The canine host becomes infected when the mosquito bites.

D. Dengue Fever

Dengue Fever.—Dengue Fever, also known as Breakbone Fever and Dandy Fever, is a rapidly spreading epidemic disease of the tropics and subtropics. The disease is sudden in its attack and is manifested by high fever, severe rheumatic-like pains in the joints and limbs; a remission of about two days follows the first attack of about three days, the second attack lasting usually but a day and is accompanied by a rapidly spreading rash. The entire course may be run in 5 to 6 days. The mortality is very low. The blood inhabiting causative organism is not known. The incubation period is said to be from 2 to 5 days and the patient's blood is said to be infective to mosquitoes from 2 to 8 days. The single successful experiment performed by Ashburn and Craig (*loc. cit.*) indicates that *Culex quinquefasciatus* (= *C. fatigans*) is a carrier but may not be a necessary intermediary host since infection was brought about after only 24 hours had elapsed between the biting of the dengue patient and the non-immune recipient.

Sufficient epidemiological evidence seems now to be at hand to regard both *Culex quinquefasciatus* and *Aëdes œgypti* (= *Stegomyia calopus*) as effective carriers of dengue.

F. Phlebotomus Borne Diseases

Pappataci Fever.—Pappataci fever, also known as three-days' fever, sand-fly fever and Phlebotomus fever, is a dengue-like disease of sudden onset, the attacks of fever lasting 2 or 3 days. It occurs mainly on the islands of the Mediterranean, Italy, parts of Austro-Hungary and China. The causative agent is unknown.

After inoculation by a Phlebotomus fly there is an incubation period of about 7 days giving rise to the active symptoms, and a brief period of probably not over 24 hours during which the patient's blood is infective. It is only during this brief period that the flies can become infected and the incubation period in the insect is apparently from 7 to 10 days.

Verruga Peruviana is a disease confined to South America (Peru and probably other parts) and is found on the western slopes of the Andes in certain narrow canyons at an altitude of from 2,800 to 9,000 feet. The disease in its initial symptoms is characterized "by a fever lasting from fifteen to thirty days, profound anemia, prostration and a high mortality. If the patient does not die in this stage, the fever begins to abate and the eruptive or verruga stage commences." The causative organism is unknown, although some have believed the so-called X-bodies or Bartonia bodies (*Bartonia bacilliformis*) to be the causal agents. According to the Verruga Expedition Report[1] the X-bodies are the causative organisms of Oroya Fever with which Verruga has been confused and hence the above error.

Townsend[2] reported having infected a hairless dog (*Canis caraibicus*). Townsend injected subcutaneously in the right shoulder of the animal a serum containing the triturated bodies of twenty female *Phlebotomus verrucarum* Townsend collected at random in a verruga canyon. The incubation period was said to have been six days when the typical eruption is said to have begun to appear. The same author[3] reports a human case which he believes to have resulted from the bites of Phlebotomus flies. Although the Verruga Expedition Report (*loc. cit.*) does not consider Townsend's evidence as conclusive the latter again represents his arguments in favor of the Phlebotomus fly theory in a paper published in the American Journal of Tropical Diseases and Preventive Medicine, July, 1915 (pp. 16-32).

Phlebotomus Flies.—Phlebotomus flies, though resembling mosquitoes somewhat, belong to another family, namely the Psychodidæ which includes the owl midges, moth-flies and sand-flies. The members of this family have both the wings and body covered with dense hairs. The wings are ovate in shape and owing to the faint transverse venation appear to have only longitudinal veins. The genus Phlebotomus (Fig. 91) includes a number of species of small size, measuring from 3 to 5 mm. in length and the females are blood-sucking.

The habits of the Phlebotomus flies are described by several authors, among them Townsend,[4] who says that the tiny blood-sucking gnats "avoid wind and sun and full daylight. They appear only after sunset, and only then in the absence of wind. They enter dwellings if not too brightly lighted, but are not natural frequenters of human habitations. They breed in caves, rock interstices, stone embankments, walls, even in excavated rock and earth materials. . . . They hide by day in similar places or in shelter of rank vegetation. Deep canyons, free from wind and dimly lighted, are especially adapted to them. Thick vegetation protects them from what wind there is by day or night. . . . The flies suck the blood of almost any warm-blooded animal, and even that of lizards in at least one known case. Thus they are quite independent of man, and this accords with the verruga reservoir being located in the native fauna."

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[1] Strong, R. P., Tyzzer, E. E., Brues, Charles T., Sellards, A. W., Gastiaburn, J. C., 1913. *Verruga peruviana,* Oroya fever and Uta. Preliminary report of the first expedition to South America from the department of Tropical Medicine of Harvard University. Journ. Amer. Med. Assoc., Vol. LXI., No. 19.

[2] Townsend, Charles H. T., 1913. The transmission of Verruga by Phlebotomus. Journ. Amer. Med. Assoc., Vol. XIV, No. 19.

[3] Townsend, Charles H. T., 1913. Human case of Verruga directly traceable to *Phlebotomus verrucarum.* Entomological News, Vol. XXV, No. 1.

[4] Townsend, Charles H. T., 1913. A Phlebotomus, the practically certain carrier of Verruga. Science, N. S., Vol. XXXVIII, No. 971.

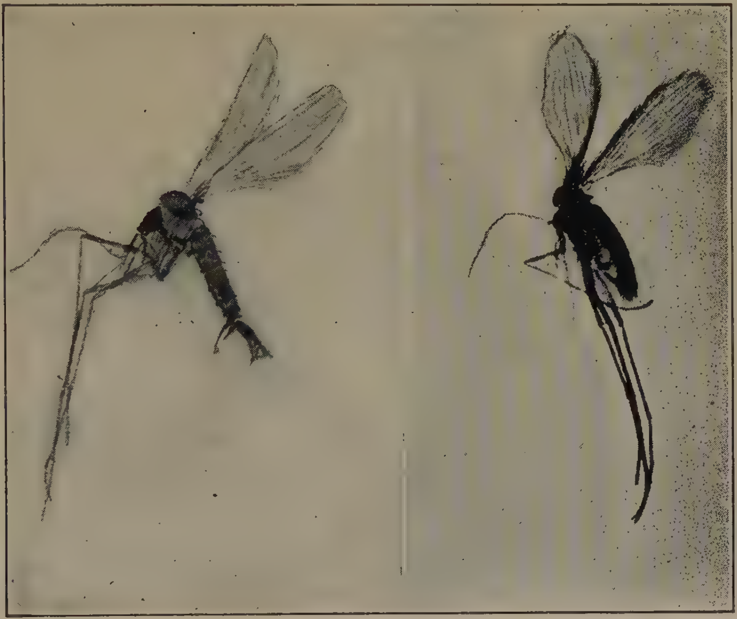

FIG. 91.—Phlebotomus or sand fly (male, left; female, right). Carriers of Pappataci fever and Verruga. × 8.

Marett[1] suggests the following prophylactic measures, viz.: Facing of walls, the removal of heaps of stones and the blocking of all holes which might serve as shelter places for the flies; also covering the ventilators with fine-meshed wire gauze, and the cleaning of all rough, made ground from weeds, so that all holes may be discovered and filled up with beaten earth. The encouragement of gardening on such grounds is, he thinks, also desirable. Large embankments should be planted with native aromatic plants such as thyme, pennyroyal, etc., and kept well earthed.

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[1] Marett, Capt. P. J., 1913. The Phlebotomus Flies of the Maltese Islands. R. A. M. C. Journ., XX, No. 2, pp. 162-171. (Abstract in The Review of Applied Entomology, Vol. 1, Ser. B, Part 2, pp. 27-29.)

The life history, though greatly influenced by temperature in general requires from 6 to 8 weeks; the egg stage, 6 to 9 days; larval stage, 4 to 5 weeks; and the pupal stage, from 6 to 16 days. Among the principal species of the genus are the following, *Phlebotomus papatasii* Scopoli, *P. perniciosus* Newst., and *P. minutus* Rond.

CHAPTER XI

MOSQUITO CONTROL

General Considerations.—The breeding habits of mosquitoes vary so widely with the species and even for localities that no anti-mosquito campaign should be undertaken without first knowing what species are to be dealt with. This will save money in the end and make results the more certain. On the other hand, a well *experienced* person could expect to achieve reasonably good results during a given mosquito season if he were placed in charge of a campaign in advance of the breeding season, even though he were unfamiliar with the local species. Such a person would no doubt continually inspect likely breeding places (such as he has proved by earlier experience) and would apply suitable control measures as soon as he has found immature stages. Two points of importance are here emphasized, namely, careful and intelligent *scouting* or inspection and *early action* in order to prevent the first spring brood of mosquitoes from coming into existence. If an anti-malaria campaign is decided upon during the summer, it is suggested that a careful inspection be made during early autumn in order to locate breeding places and then apply remedial measures at such a date as will result in the destruction of the last brood; this will greatly reduce the number of overwintering forms responsible for the first spring generation and hence materially lighten the early work, but should not cause the inspector to lessen his vigilance.

With the thought clearly in mind that no mosquito ever came into existence without water in which its developmental stages were passed, and that very small quantities of suitable water may produce myriads of mosquitoes, the importance of keeping all collections of water, however small, under strict surveillance becomes obvious. As a general rule, based on a knowledge of mosquito life history, water that remains standing and exposed to mosquitoes during their breeding season for ten or more days is a potential nuisance. Climatic conditions and character of the water are critical factors.

Drainage.—Drainage as a mosquito-control measure hardly falls within the scope of drainage engineering. There is probably little in mosquito control drainage that would commend itself to the engineer, either sanitary or otherwise. Where great swamps are to be drained or drainage canals are to be established in connection with irrigation districts engineering skill will be needed, but it all too frequently happens that during such operations unless the "mosquito man" is on the job an increase of mosquitoes will be noticed due to the multiplication of smaller and more favorable mosquito-breeding pools incident to the major operations. These small pools are as a rule of no interest to the average engineer, but may nevertheless be a greater menace to health than the original swamp. This discussion therefore does not pertain to drainage engineering.

Usually little trouble is encountered in dealing with such smaller accumulations of stagnant water as occur in roadside ditches where often most of a community's mosquitoes originate. If the ditch defects cannot be overcome, oil may usually be applied without danger to useful vegetation or domesticated animals. Swampy or marshy areas may often be corrected by one or more properly placed ditches, or the deepening of a channel to insure a flow of the water. Seepage outcrops frequently produce dangerous swamp areas with numerous puddles in depressions, hoofmarks, etc. This may be dealt with by a system of ditches at right angles to the outcrop to collect the water and discharge it into two converging main ditches leading away to a near-by stream.

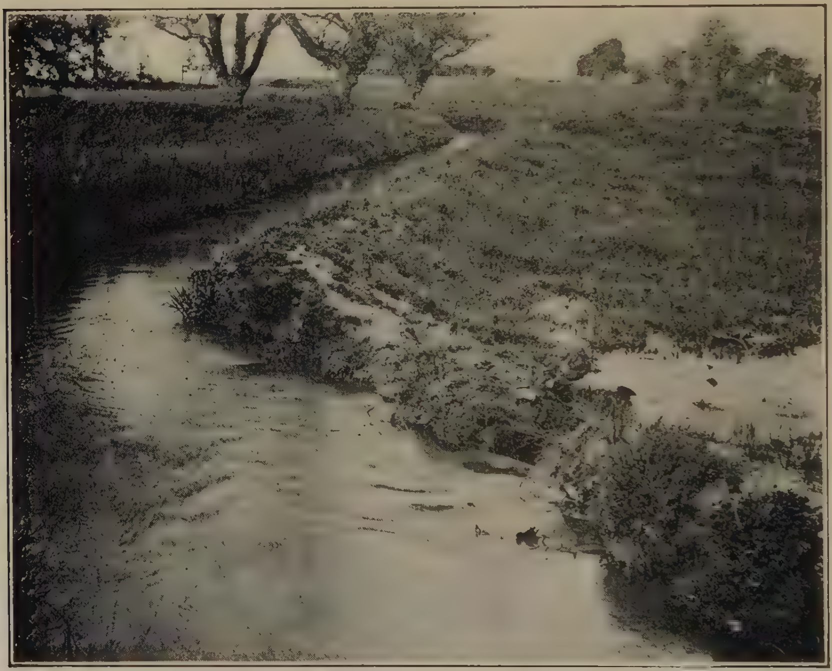

Fig. 92.—Breaks in the irrigation ditch are responsible for considerable inundation, producing favorable breeding places for mosquitoes, especially Anopheles. The rapidly running water in the ditch is unfavorable for mosquitoes.

It not infrequently happens that no outlet can be found, when it is suggested that all the seepage be led to a deep, clean-edged *sumpage ditch* or *puddle* which should be inspected at regular intervals to determine if any mosquito breeding has occurred, if so, a heavy coating of oil should be applied. It may also happen that surface accumulations of water may persist owing to hard-pan (impervious subsoil, etc.); this may be handled at times by wells sunken into the deeper layer of sand or gravel thus affording a method of *vertical* drainage. The use of dynamite in ditch construction and similar drainage operations should not be overlooked.

Irrigation.—It is quite commonly asserted that malaria makes its appearance together with irrigation. That is apparently often true, but it need not be so if proper attention were paid to the best methods of irrigation. Certainly southern California is necessarily the scene of much irrigation, yet malaria is quite scarce, therefore irrigation as such cannot be a factor. The matter simply resolves itself to relative abundance of water; i.e., where this is abundant, as in northern California, it is used unsparingly and without regard to "leaky" ditches (Fig. 92) and great waste, resulting in ideal swamp areas for the propagation of the Anopheles mosquito.

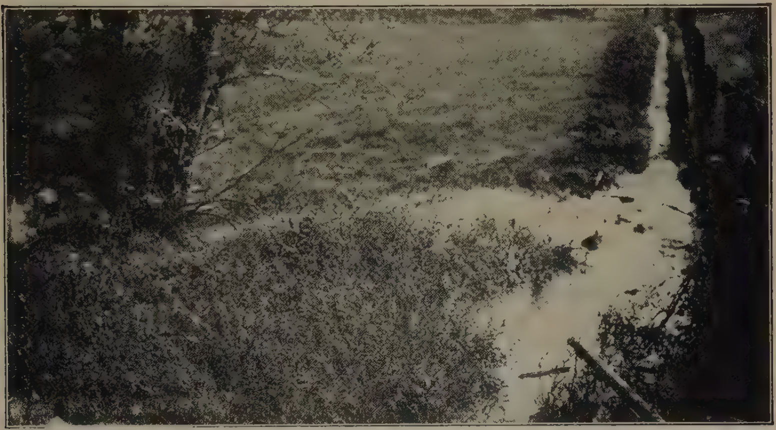

FIG. 93.—Drainage water resulting from irrigation, a source of myriads of mosquitoes. The small ditch in the background will remove the difficulty.

With proper attention to irrigation methods, particularly drainage (Fig. 93), and the use of concrete, tile or metal waterways to prevent useless lateral seepage there need be absolutely no malaria associated therewith. Water should not be permitted to stand in pools for long periods,—usually twenty-four hours is sufficient. Water which has been standing ten days or over is dangerous, because it only requires ten days at the shortest in midsummer for the commoner species of mosquitoes to develop from the egg to the adult. Water that runs freely in ditches is not favorable to the propagation of these insects. The poorly kept, weed-grown ditch is a bad investment in every way, an eyesore and a menace to health.

Receding Streams.—As long as a river is high there will be little or no opportunity for mosquitoes to breed along its banks, but later in the summer, e.g., June or July, many pools may be left behind by the receding water (Fig. 94). The stagnant water becomes laden with algæ and soon Anopheles are breeding in abundance. The same condition also commonly prevails along smaller streams. Many mosquito wrigglers may often be found developing in pools covered with green "scum," and along the edges of the stream or creek where the current is sluggish. In both cases the situation is controllable, as has been demonstrated. The pools along the banks of the receding river can be drained off, in nearly all cases, or can be thoroughly oiled. Thus a river town need not necessarily be a malarial town. And, furthermore, the banks of a river or creek can be kept clean at a comparatively small cost and this need only be done for a distance of about one mile on either side of the community; in most cases a shorter distance will serve very well because the Anopheles mosquitoes are

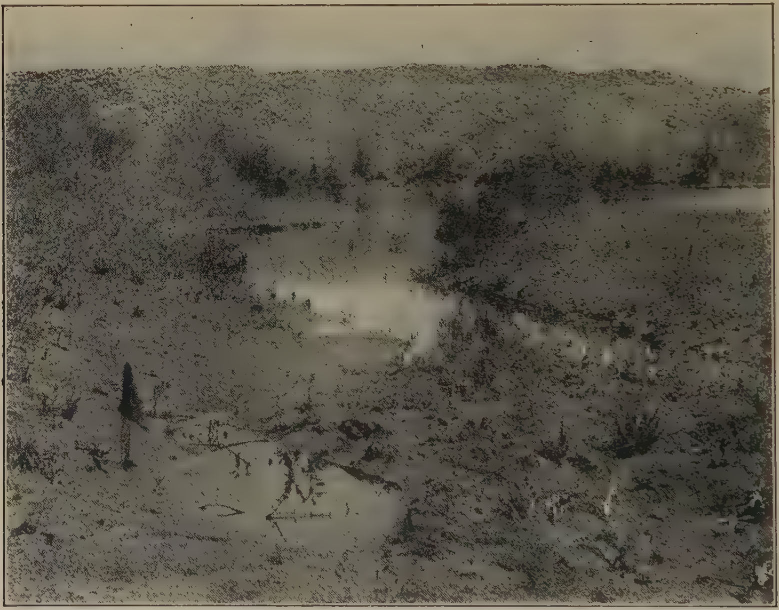

FIG. 94.—Receding streams leave pools of standing water along the banks, in which mosquitoes may breed plentifully.

not strong fliers, being bred, as a rule, very near the place where they are found.

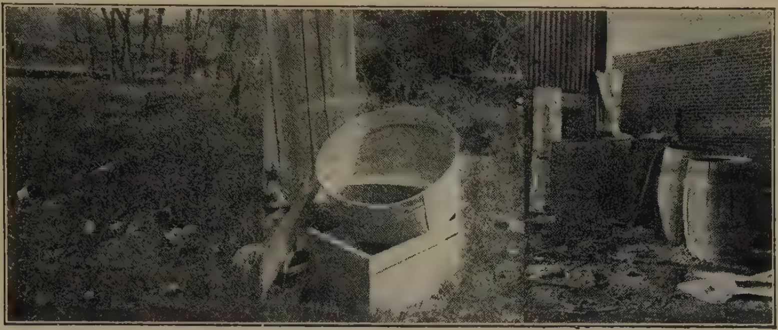

FIG. 95.—Tin cans, tubs and barrels in which water may stand and breed mosquitoes.

Sundry Nuisances.—Water holding receptacles (Fig. 95) of many kinds may prove suitable situations for mosquito breeding and must not be overlooked by the "mosquito man." However, it sometimes happens that an overemphasis of the tin-can results in attracting the attention away from more important matters, such as dripping hydrants (Fig. 96), stagnant ditches, etc. Indeed the water in tin cans unless in shady situations usually becomes too hot for mosquitoes during most of the summer. Heaps of broken gourds commonly reek with mosquito larvæ, tubs and barrels of water frequently produce many of these pests, though rather rarely anophelines. Stagnant water in poorly constructed street gutters (Fig. 97) is often a serious menace.

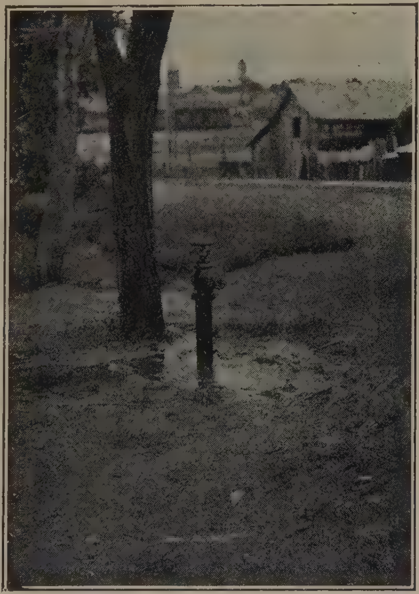

FIG. 96.—The leaking faucet with the resulting pool of water is often a constant menace in the entire absence of other mosquito-breeding sources.

Oiling.—One hardly thinks of mosquito control without also thinking of oil, which accounts for the great quantities of oil used in this connection, much of it without effect and with much waste. One should first consider drainage (Fig. 98) and secondly oiling or some other accessory method.

The use of oil is generally believed to be based on its suffocating property in covering the surface of water to which mosquito larvæ cling in their effort to secure air. It has been experimentally shown by Freeborn and Atsatt[1] that the toxicity of petroleum oils as mosquito larvicides increases with an increase of volatility, i.e., the more volatile oils produce the more marked lethal effects, due to the penetration of the tracheal tissue by the volatile gases of the oil. In the heavier oils (boiling point greater than 250° C.) the effect due to volatility becomes secondary to the actual contact effect or mechanical plugging of the tracheæ resulting in suffocation.

FIG. 97.—Stagnant water in gutters breeds numerous mosquitoes, often Anopheles.

As a practical agent for the destruction of mosquito larvæ and pupæ, the oil should spread readily without breaking up into patches between which the water is not affected and it should have lasting qualities. The so-called crude oils or black oils, when applied to ponds, break up into patches, and wrigglers come to the surface in the oil-free areas. A number of prominent failures in mosquito control have been the result of crude-oil treatment. Crude oil, furthermore, cannot be used well in ordinary spray pumps. The lasting quality is, however, very good. Kerosene spreads most satisfactorily and does its work quickly, but evaporates in a comparatively short time, thus requiring frequent repetition. A mixture of the two can very well be made which will bring about more nearly the desired results. Our best results have been obtained with a mixture of approximately equal parts of crude oil and kerosene, though the proportion may perhaps safely range to three parts of the former to one of the latter. We have also used successfully a treated stove oil of about 28° Beaumé.

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[1] Freeborn, S. B., and Atsatt, R. F., 1918. The effects of petroleum oils on mosquito larvæ. Journ Econ. Ento., Vol. II, No. 3, pp. 299-307.

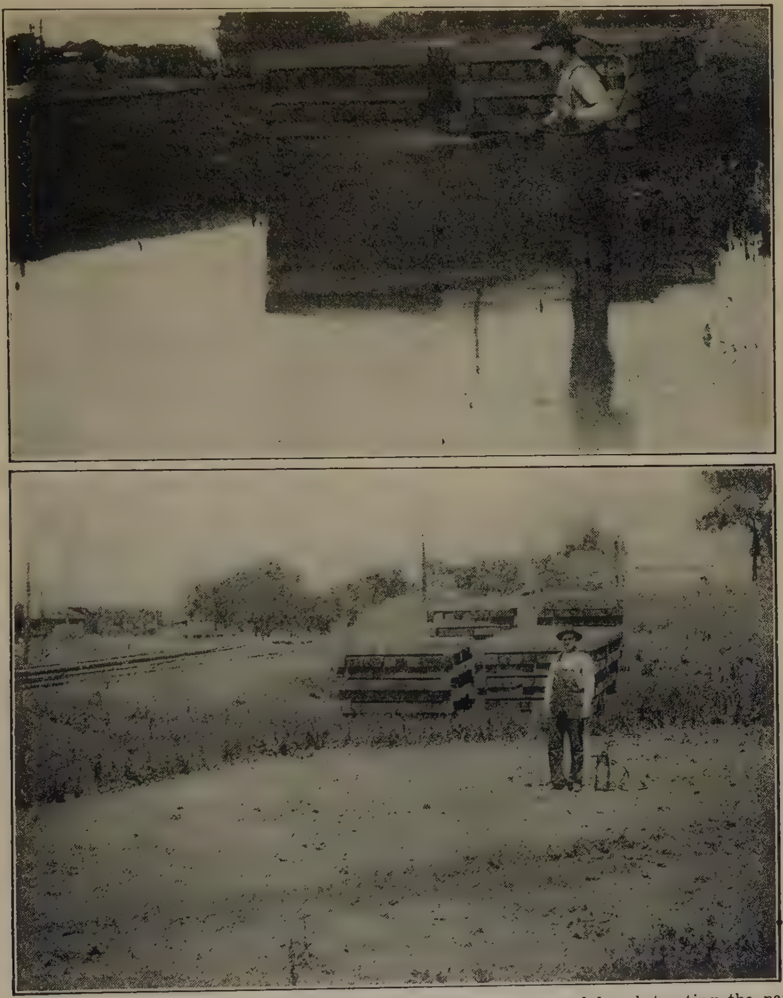

Fig. 98.—Upper figure shows a pond adjacent to a railroad and caused by obstructing the natural drainage. A source of many mosquitoes every year. Oiling, while serving the purpose, requires repeated expenditure of time, labor and money. The lower figure shows the same spot after it had been permanently corrected by the railroad company.

Oil purchased on the market as "crude oil" varies from 12° to 18° Beaumé, while "stove distillate" varies from 28° to 32°, and water-white kerosene from 40° to 42°. Knowing the specific gravity of the oil purchased, it can easily be calculated how to mix with lighter or heavier oil in order to obtain the required consistency. Thus if kerosene (42°) is at hand and crude oil (15°), use about ten gallons of the former to twelve gallons of the latter. For spring and autumn, 28° to 30° Beaumé is to be recommended, while for summer use a heavier oil at about 26° is preferable. To mix the oils it is necessary to use the spray pump, i.e., repeatedly fill the chamber with oil in proper proportions, introducing the nozzle end of the hose, and churn a few minutes.

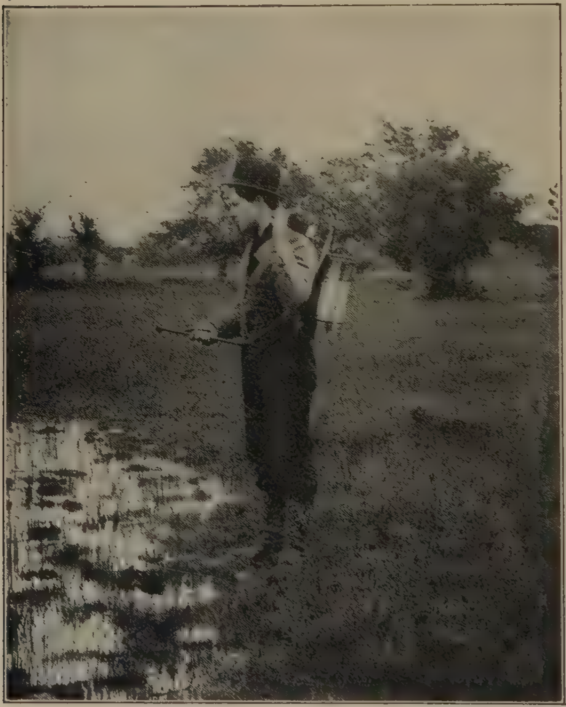

FIG. 99.—An ideal Anopheles breeding place. The water is shallow and clear, with much vegetation. Also shows use of knapsack spray pump.

How to Apply Oil.—Simply pouring on the oil with a dipper is wasteful and requires some little time if all the smaller adjacent pools of water are to be treated. Experience has taught that the small, apparently insignificant pools of water are in reality the greatest menace and are commonly overlooked. The use of a knapsack spray pump (Figs. 99 and 100) of five-gallon capacity is highly recommended. This can be strapped on the back and will provide enough oil for twenty minutes' continuous spraying or one or two hours of ordinary oiling. A small-sized "pyrene" fire-extinguisher is also a handy and useful substitute for the large spray pump. Operators must be careful not to spill the crude oil on the body particularly when working on hot sunshiny days.

Other Methods of Applying Oil.—A variety of schemes have been devised to secure a more or less continuous flow of oil to small water surfaces in order to avoid repeated spray pump oilings and also to overcome the handicap of spray pump portage and manipulation under certain difficult conditions. Oil-holding substances, such as sawdust and cotton waste, are commonly employed. A bundle of cotton waste soaked in a heavier oil and cast into a pool of water will give off a thin film of oil for about a week.

A small camp of soldiers was situated near an abandoned sawmill and a great hill of sawdust was available for filling numerous Anopheles breeding pools in the neighborhood. While observing this work the writer noticed that oil soaked sawdust continued to give off a thin film of oil to the water for days. The liberal use of this oil-soaked sawdust proved most useful in the control of mosquitoes. For use on a smaller scale the writer recommends mixing sawdust and ordinary fuel oil in a larger pail and strewing the oiled dust by hand where needed. A small winding creek much overgrown with shrubbery and weeds, with steep banks and many stagnant pools has been very successfully treated in this manner. Further applications are determined by occasional inspections for evidences of mosquito breeding.

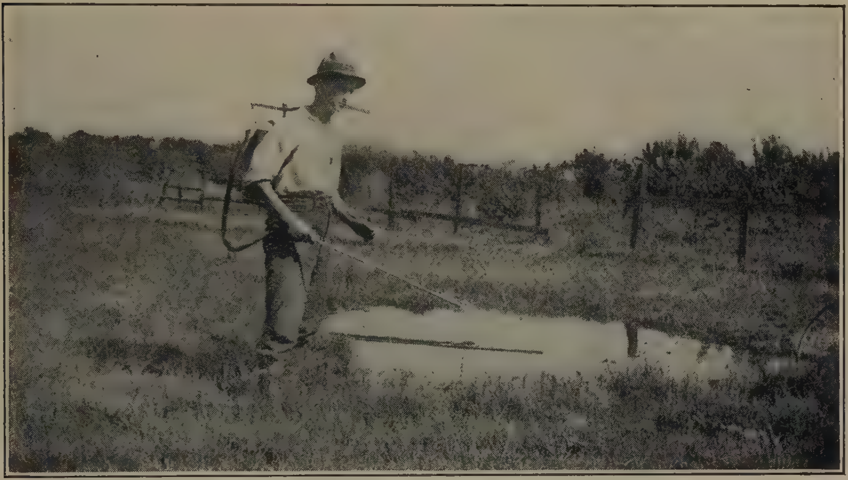

Fig. 100.—Showing use of knapsack spray pump in mosquito control.

Oil Drips.—The use of oil drips is well described by Le Prince[1] as follows:

> "The use of 'oil drips' for intermittent or continuous application on ditches or streams containing moving water has proved satisfactory. Where the heavy oils are used the drip can is placed 3 to 4 feet above the water surface so that the drops of oil strike the moving water with a blow and at once change into a thin oil film. The stand, base, or object that supports the drip can must be secure and beyond danger of removal by flood waters. Cans of from 5 to 30 gallons' capacity are used for dripping. The drip

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[1] Le Prince, J. A. A., 1915. Control of Malaria; oiling as an antimosquito measure. U. S. Public Health Service, Reprint No. 260 (U. S. Public Health Reports, Feb. 26, 1915).

outlet is placed several inches from the bottom to allow of the settling of the heavier constituents of the oil that might clog up the outlet. The oil being warm in the daytime flows more freely than at night. The object of a dripping stream is to allow a sufficient number of drops of oil to fall on the moving water surface to form a continuous thin film. The water in ditches or streams so treated and kept fairly well cleaned or free from obstructions will convey the oil to all parts of the stream below the drip can and it will keep a film of oil on the places of minimum or zero current. It is in this quiet water that most mosquito larvæ are apt to occur.

"On ditches and streams having an average width of water surface of one foot, from 10 to 20 drops of oil per minute are applied. The quantity of oil required depends upon the spread of oil, the alignment of the stream, roughness of banks, grade, obstructions, etc. For economic control a trial should be made at each ditch or stream where a drip can is used to determine the desired rate of flow. The drip can should be regulated accordingly. In many cases the drip need be operated continuously for only one or two days of each week. With larger streams it may be found necessary to operate the drip continuously day and night. On long streams or ditches it is at times necessary to use several drip cans. They are then so located that the next drip can is installed approximately at the point where the effect of the drip at the source disappears. Continuous dry weather may make it become necessary to discontinue the use of some drips or to change their location. At such season, pools will be left isolated at the sides of a stream and will have to be filled, or separately treated with oil by other methods. When the stream stops running the use of drips is discontinued and any water left in the stream bed is oiled with a knapsack sprayer or watering pot. With the best care oil drips will clog, due to suspended solids or heavy constituents in the oil, and must be adjusted as often as necessary. The disadvantage of oil drip cans is that they will not give satisfactory service without proper attention, may become clogged, or be washed away by floods. Their use is generally more effective and economical than the direct application of oil by sprinkler or knapsack sprayer for water in motion. A thinner, but satisfactory, film of oil is obtained from the heavier cheap oils.

"A crude but cheap and easily made drip can consists of a five-gallon can such as is used for shipping illuminating oil. A hole is made in its bottom with a two- or three-inch round nail. A wad of loose cotton is wrapped around the nail just below its head. The nail is then pushed through the hole on the inside of the can, and crude oil is put in the can, which is suspended or placed on a stand over the ditch. By pulling the point of the nail downwards and gently pushing it upward the flow of oil may be decreased or increased as desired.

"For thinner oils the five-gallon can with metal discharge tap may be used and the tap adjusted to give within a few drops of the number desired to be discharged per minute. When oils less fluid than kerosene are used the spout or discharge point should be one or more inches above the bottom of the container, in order to prevent clogging of the very small escape outlet used."

When to Apply Oil.—Oil should be applied whenever and wherever the wrigglers and tumblers are found, even though permanent correction is planned. This will prevent them from being washed out into some other situation where they would be liable to complete their transformation. The frequency with which oil must be applied depends on the rate of development of the wrigglers and the evaporation of the oil,—both conditions being dependent on the temperature. Therefore, more frequent applications are necessary during midsummer, when with the oil mentioned above, spraying should be repeated at least every twelve days, and under cooler conditions (averaging 50° to 60° F.) every three weeks. If it requires only ten days for some mosquitoes to pass through their entire transformation, one might think that applications of oil every twelve days would not be often enough, but it must be remembered that the oil kills all wrigglers and tumblers shortly after contact and the film remains on the water for about two days, sometimes longer, during which time any adult mosquito, intending to lay eggs, is killed on coming in contact with the oil. After the oil has evaporated quite largely, the breeding may begin again, but the next application of oil will catch the oncoming brood before the ten days necessary for complete development have expired.

"Larvicide," generally used in the Panama Canal Zone, is prepared from crude carbolic acid. Its manufacture and method of application are fully described in an article by S. T. Darling in the American Journal of Public Health for February, 1912. From this the following is quoted:

> "One hundred and fifty gallons of crude carbolic acid are heated in an iron tank having a steam coil with steam at fifty pounds pressure. Two hundred pounds of finely crushed and sifted common rosin are dissolved in the heated acid, and then thirty pounds of caustic soda dissolved in six gallons of water are added. There is a mechanical stirring rod attached to the tank. The product is ready in a few minutes, yielding about 3½ barrels. As a mosquito larvicide it is used by spraying an aqueous emulsion (one part of larvicide to five of water) over the surface and along the margin of pools and ponds or other mosquito-breeding places so that the resulting dilution of the larvicide has a thin, milky opalescence representing approximately a dilution of 1 to 5,000."

Water thus treated is poisonous to animals.

Arsenic.—The fact that anopheline larvæ feed upon minute floating substances on the surface of the water led to experimentation with poisonous dusts and similar substances which would remain afloat on the water. Among the arsenicals tested Paris green according to Barber and Hayne[1] proved most satisfactory. Lead arsenate, arsenic trioxid (white arsenic), and calcium arsenate, proved inferior and arsenopyrite was wholly ineffective. Barber and Hayne state that the Paris green should be diluted at the rate of one part of poison to 100 parts of inert dust, rotten wood dust or fine sand, preferably the former, mixed with some fine clay, in order to dilute the poison and minimize the risk of poisoning the operator or the water treated. It is stated that about 10 cc. (approximately 12 grains, 0.43 ounces avoirdupois, 0.6 cubic inches, or two level teaspoonfuls) will treat 90 square meters (1,000 square feet) of surface. The distribution of the dust is said to be best accomplished by simply throwing it into the air by hand, a light wind carrying a slowly settling cloud of it to the surface to be treated. Deep ditches are reached by the pole and bag method. The best results are obtainable on sunny days after the dew has disappeared from the vegetation. The treatments should be repeated within ten days during the height of the breeding season.

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[1] Barber, M. A., and Hayne, J. B., 1921. Arsenic as a larvicide for anopheline larvæ. U. S. Public Health Reports, Vol. 36, No. 49, pp. 3027-3034.

Concerning the dangers from the use of this poison the above authors state:

> "In our experiments we have used no precautions other than to stand to the windward of the dust cloud—the place where one would naturally stand in distributing dust—and we have experienced no harmful results whatever. However, even with the small quantities used in larvicide work, it is well to remember that one is working with a poison and that some precautions should be taken at least until the matter is further investigated. It is probably sufficient to keep to the windward of the dust clouds and to avoid inhaling the dust as far as possible. In case a great deal of exposure is necessary, one should use some precaution to keep any large amount of Paris green from entering the clothing or accumulating on the skin. The danger to domestic animals through drinking treated water seems very remote. . . . We have never observed any effect of the poison on culicine larvæ or on any aquatic insect or animal, however delicate, other than the surface feeding anopheline larvæ. In particular, we have not observed any indication of harm to top-feeding minnows or to any other natural enemy of larvæ."

The same authors believe arsenic commends itself because of its cheapness (at 25 cents per pound the amount sufficient for at least 1,000 square feet, 10 cc. would cost about seven-tenths of a cent), portability, ease of distribution by means of the wind, and the possibility of using it over areas difficult of treatment by other methods. Its chief disadvantage is that its use is limited to anopheline larvæ.

Copper Sulphate.—Treating water with copper sulphate ($CuSO_4$) for the destruction of mosquito larvæ and pupæ has been proved ineffective, but it is nevertheless useful in cases where stagnant water is covered so badly with algæ as to retard the effect of insecticides. The writer has invariably had better results with oil applied to algæ-covered ponds after liberal treatment with copper sulphate, than when the latter was not applied. Copper sulphate is ordinarily used not in excess of one part per million of water.

Tobacco Decoctions.—The writer has thoroughly tested the efficiency of tobacco decoction, both in the laboratory and in the field, and has found it very effective, but the expense is prohibitive when it is used on a large scale. Sulphate of nicotin (Black leaf 40) made by the Kentucky Tobacco Products Company, was found to effectively destroy all wrigglers and tumblers when used in the ratio of 1 part to 750 parts of water. Greater dilution proved uncertain for the pupæ, but 1 to 1,000 is still effective for larvæ. In field work this material was effectively used on smaller pools and also on a good-sized quarry-hole pond, but the cost proved too great. Ordinary "Black leaf" tobacco decoction cannot be used effectively in a greater dilution than 1 part to 20 of water. It must be remembered in all cases that a material in weaker strengths would be just as useful and less expensive provided it killed the insect, even after a day or two, and this factor was borne in mind during the progress of experimentation.

Smith found that "Nicofume" destroys all small wrigglers at the rate of 1 part to 2,500 parts of water, and all wrigglers and eventually all tumblers at the rate of 1 part to 1,500 parts of water. Rapid destruction was accomplished by using 1 part of "Nicofume" to 750 parts of water.

Screening.—Biting habits of mosquitoes differ considerably as already explained, e.g., *Anopheles punctipennis* is a typical porch biter which points to the necessity for properly screened porches for evening or night use, and *Anopheles quadrimaculatus* and *A. maculipennis* are typically indoor species finding their way inside even though no other opening is left but the chimney. The latter species stick close to their food supply and follow man into his home, hence screened doors opened to admit human beings also admit mosquitoes, and despite good screens malarial infection may nevertheless occur. This fact emphasizes the need of daily destroying the invading anophelines.

The following simple suggestions will prove useful: (1) The best size mesh for all purposes is No. 18, i.e., 18 strands to an inch. (2) Screen doors should be made to open outward, should fit snugly, should be provided with a strong spring, and a strip of board should be nailed on the lower panel for the foot to push against when kicking open the door. (3) Window screens should screen the entire opening and should fit perfectly. (4) Fireplaces should be completely sealed during the mosquito season. (5) Sleeping porches and porches used for sitting during the evening must be carefully screened. (6) Vestibuled doors are strongly recommended. (7) Screens must be frequently examined and kept in good repair. (8) Mosquito bars or bed nets usually only afford false security and persons occupying the same are commonly bitten before retreating beneath the same.

Destroy Invading Anophelines.—The indoor anopheline is usually more to be feared than the one in the field. Its opportunity to feed on human blood and consequently to become infected with malaria is largely increased. The daily destruction of all anopheline invaders would certainly reduce the danger from malaria to a minimum. In carrying on malaria control operations at various points near Newport News, Va., during the late war the writer emphasized this particularly for camps so situated that the usual mosquito control methods could not be employed. Additional precautions were exercised such as the wearing of head nets, repellents for hands and wrists and a biweekly dose of 30 grains of quinin.

Repellents.—Night laborers, watchmen, pickets, and others compelled to be on duty at night are, of course, exposed to the bites of mosquitoes and should exercise some precaution at least against these pests. Repellents of several kinds have been used with more or less success. The writer has found *oil of citronella* to be one of the most reliable deterrents when simply rubbed on the hands and face; a dozen drops or thereabouts being placed in the hollow of the hand and thus applied.

To this oil may be added various other ingredients; for example, Howard has found the following mixture most effective, viz.: 1 ounce of citronella, 1 ounce spirits of camphor, and ½ ounce oil of cedar. Howard found this very satisfactory against *Culex pipiens* by applying a few drops on a bath towel hung on the head of the bed. He, however, adds that it is not effective against the yellow-fever mosquito, which begins biting at daybreak when the oil has lost most of its strength.

Other deterrents used and recommended by various authors are: a mixture of castor oil, alcohol, and oil of lavender, equal parts; or a few drops of peppermint or pennyroyal, oil of tar, oil of cassia, or simply pure kerosene.

The following mixture is known as "Bamber Oil" and has been used with fair success by the author, citronella oil (not lemon grass oil) 1½ parts, kerosene (paraffin) 1 part, coconut oil 2 parts. To this mixture 1 per cent carbolic acid is added.

Fumigants.—Knowing that mosquitoes often hibernate in great swarms in basements of buildings, cellars, and other favorable situations, it becomes necessary to destroy these in order to prevent them from propagating in the spring of the year. A number of very satisfactory fumigating agents may be mentioned, such as pyrethrum powder, sulphur dioxid, fumes of cresyl, pyrofume (a turpentine by-product), and Jimson weed fumes. It is recommended to use powdered Jimson weed (*Datura stramonium*) at the rate of 8 ounces per 1,000 cubic feet of space, mixing it with one-third its weight of saltpeter to facilitate combustion. The mixture is to be spread on a tin pan or stone and ignited at several points. The fumes are not dangerous to human life.

Mosquito Bites.—Mosquito bites, while perhaps never serious in themselves, may lead to blood poisoning through scratching with the finger nails in the attempt to relieve the irritation, often intense. To relieve this irritation any one of the following may be applied, viz.: ammonia, glycerin, alcohol or iodin. According to Howard the most satisfactory remedy known to him is the application of moist toilet soap. He also mentions touching the puncture with a lump of indigo as affording instant relief, or touching the parts with naphthaline moth balls.

Natural Enemies.—Efficient enemies of mosquitoes are found among the surface-feeding fishes, which are practically all of small size. Unfortunately, where mosquito larvæ are found there are also abundant other aquatic insects, so that the stock of fish must be correspondingly large in order to hold in check the insects aimed at. In such places where it is undesirable to apply oil and the water is not too shallow throughout its entire extent, fish may be introduced. Ornamental ponds, reservoirs, springs, cisterns, tanks and the like are among the instances in which surface-feeding minnows may be found useful.

The common goldfish (*Carassius auratus*) is at the same time one of the most ornamental and efficient fishes in this respect. The following quotation from Howard[1] after Underwood, referring to an ornamental aquatic garden near Boston, in which mosquitoes were kept in check by goldfish is apropos:

> "I took from the pond a small goldfish about three inches long and placed it in an aquarium where it could if it would, feed upon mosquito larvæ and still be under careful observation. . . . In the first day, owing perhaps to being rather easily disturbed in its new quarters, this goldfish ate eleven larvæ only in three hours, but the next twenty-three were devoured in one hour; and as the fish became more at home the 'wigglers' disappeared in short order whenever they were dropped into the water. On one occasion twenty were eaten in one minute, and forty-eight within five minutes. This experiment was frequently repeated and to see if this partiality for insect food was characteristic of those goldfish only which were indigenous to this locality experimented with, some said to have been reared in carp ponds near Baltimore, Maryland, were secured. The result was the same. . . ."

Similar results have been attained in a number of places both on the Atlantic and Pacific coasts.

One of the most valuable articles touching the control of mosquitoes by fish is that of Seal[2] for the Scientific American, in which he makes the following statements: "The goldfish is somewhat lethargic in habit, and is also omnivorous, but there is no doubt that it will devour any mosquito larvæ that may come in its way or that may attract its attention. The one great objection is that they grow too large, and the larger will eat the smaller of them." The same observer concludes that "a combination of the goldfish, roach, and top minnows would probably prove to be more generally effective in preventing mosquito breeding than any other."

[1] Howard, L. O., 1910. (*Loc Cit.*)

[2] Seal, William P., 1908. Scien. Amer. Suppl., Vol. 65, No. 1691, pp. 351-352.

Perhaps the most useful of the top minnows is *Gambusia affinis*, a hardy, rapidly breeding, prolific surface feeding fish which within its range normally frequents shallow water suitable for mosquito propagation. It is viviparous and is said to produce as many as six to eight broods in a season with an average of forty to a brood. The size of the fish ranges from 1¼ inches in length in the male to about 2 inches in the female. This fish is easily propagated and adapts itself to a variety of conditions with ease.

Other fish which have been found useful are *Heterandria formosa, Fundulus diaphanus*, and *Fundulus dispar* for fresh water and *Cyprinodon variegatus, Fundulus heterocliteus, Fundulus similis, Fundulus majalis* and *Lucania para* for salt or brackish water. To these may be added a number of species as listed by various authors notably Hegh[1] and Radcliffe.[2]

In Guayaquil, Ecuador, the yellow-fever-mosquito problem was solved according to Connor[3] by the use of fish. Connor states that the domestic water supply is delivered to the houses daily and is stored in tanks and other receptacles, there being at the time of his writing about 7,000 of the former and 30,000 of the latter such as barrels, oil cans, earthenware bowls, etc. In these various containers yellow fever mosquitoes developed in countless numbers. Experimentation with several species of fish finally resulted in the selection of the *chalaco* (*Dormitator latifrons*—Family Gobiidæ). These fish were furnished to the Yellow Fever Service by local fishermen, placed in a specially prepared well, the conditions of which approximated those of the stream from which the fish were taken. After a few days the fish were removed to a second well, the water of which was the same as that used by the city. Connor writes further as follows:

> "The fish are then taken from the wells and placed in tins or pails and delivered to the inspectors. Instructions have been given to each inspector that every fresh-water container in his district is to be supplied with one fish, regardless of the presence or absence of mosquito larvæ in the container at that time. The public is encouraged, personally, by notices in the newspaper, and by the inspectors themselves, to exercise reasonable care in protecting the fish. The public of Guayaquil has responded in a whole-hearted manner to the requests of the Yellow-Fever Service, and many families have in their possession at this time the identical fish which was given them to mosquito-proof their water container nearly eighteen months ago.
>
> "More than 30,000 water receptacles have in this way been purged of mosquito larvæ in a relatively short time and at a minimum of expense.

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[1] Hegh, E., 1918. Comment nos planteurs et nos colons peuvent-ils se protéger contre les moustiques qui transmettent des maladies. Minister of Colonies, Service of Agriculture of Belgium, No. 4; 200 pp.

[2] Radcliffe, L., 1915. Fishes destructive to the eggs and larvæ of mosquitoes. U. S. Dept. of Commerce, Bur. of Fisheries, Circ. 17, pp. 1-19.

[3] Connor, Michael E., 1921. Fish as mosquito destroyers. Natural History, Vol. 21, No. 3, pp. 279-281.

With the continued use of fish it is believed that the yellow-fever mosquito can be reduced to such small numbers that, should a few cases of the disease be introduced into the community, it would not spread."

Salt-marsh Control.—Because of tides, condition of the marshes, differences in the habits of salt-marsh mosquitoes and other factors, the control of the salt-marsh pest is a matter that requires special study and experience. The rich reward in comfort and reclaimed land has offered an added incentive to those engaged in this work and better methods are continually being sought and developed. Strong public-spirited organizations have taken hold of this work both on the Atlantic coast, particularly in New Jersey, and on the Pacific coast, particularly San Mateo (California) and neighboring cities, with most gratifying results.

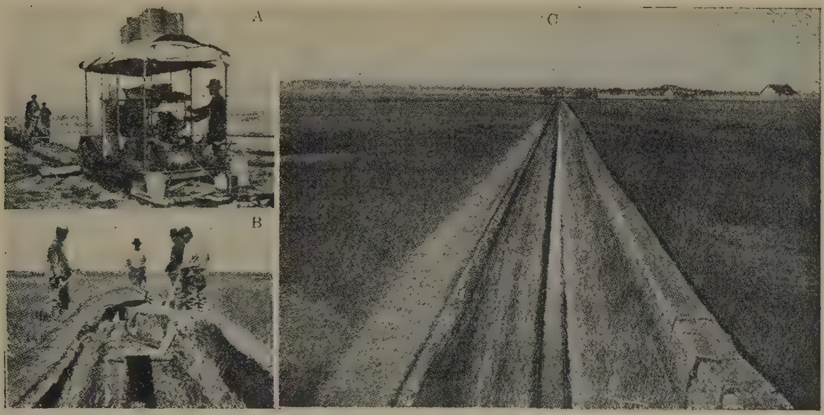

Fig. 101.—Showing (A) ditching machine (Eaton ditcher); (B) method of removing sods; (C) a ditch cut in a New Jersey salt marsh by the ditcher.

The parallel system of ditching with the lines run close enough to remove the surface water is usually practiced. Water holes are generally connected to these parallel ditches by spurs or are filled with earth from the near-by ditches. The ditches are commonly 10 by 30 inches and it is estimated that from 90 to 600 linear feet, with 200 to 300 feet as an average (Headlee[1]) are required per acre of marsh. Headlee also points out that "the greater the tide drop and the shorter the ditch, the greater is its efficiency and its ability to keep clean." "Every ditch," he states, "should have a strong tidal outlet and no ditch depending on a single outlet should be over one-quarter of a mile long." Ditches are now commonly dug by machine (Fig. 101). These machines are described as follows:

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[1] Headlee, Thos. J., 1916. Some recent advances in knowledge of the natural history and the control of mosquitoes. New Jersey Agric. Exp. Sta. Bul. 306, 26 pp.

> "Essentially the machine consists of a gasoline power plant placed on a pair of 12-foot long, 12-inch wide and 2-inch thick planks that are set within 5 feet of each other and strongly bound together with crossties. The front and rear ends of the machine each bear a revolving drum, upon which a 500-foot ¾-inch steel cable is wound. When the power plant must be moved forward or away in another direction the anchor to which this front cable is bound is carried out in the desired direction and thrown into the sod. The power is then applied to the drum and the plant is drawn up to the anchor.
>
> "The plow or trencher consists of two 12-foot long, 10-inch wide and 2-inch thick planks set parallel and 10 inches apart. Suspended between these planks are two cutters. The point of the forward one is 15 inches below the under sides of the planks and the point of the second 30 inches below. As the machine is pulled forward each cutter shears out and brings up a piece of sod 10 inches wide and 15 inches thick which it deposits as a long ribbon on one side of the ditch. This plow is attached to the power plant by a 500-foot steel rope which is wound up on the rear drum, while the power plant is standing anchored ahead.
>
> "With a machine of this sort, which can be had for $1,750, and five men it is possible to cut 3,000 feet of trenching a day and in some cases more.
>
> "Competition and the invention of this machine have cut the cost of ditching from 2½ cents a linear foot in 1912 to less than 1½ cents, and are bound to bring it lower yet. The operating and up-keep cost of ditching with this machine, as shown by cutting hundreds of thousands of feet in the past two years, does not exceed one cent a linear foot."

Low-lying and shut-in marshes cannot be controlled without the use of dikes and tide-gates. Furthermore, it has been found in some of the work near San Francisco during the past few years that the use of pumps greatly facilitates the drainage of holes caused by grading and other building operations.

Rice Culture and Malaria Mosquitoes.—Careful studies have been made by investigators to determine to what extent rice fields are responsible for the existence of mosquitoes, notably anophelines. Thus Purdy[1] reports that in his Arkansas studies[2] he found both Culex and Anopheles mosquitoes (*A. quadrimaculatus*) breeding in moderate abundance within the rice fields as well as in ditches and puddles outside the rice fields, while in his California investigations he found mosquito breeding (both Culex and Anopheline) to be practically absent from the rice fields themselves, but that moderate to heavy production goes on in near-by seepage puddles and roadside ditches (Fig. 102). Purdy found that for one mosquito produced by the rice fields, the seepage puddle produced five and the ditch forty-four. It is of importance to know that the same author[1] continued his investigation during the following season (1920) and reports practically no breeding for the same fields but in three other fields there was more or less breeding, indeed the rice fields in the vicinity of Anderson (Calif.) and particularly the seepage pools proved to be prolific in their anopheline production and therefore a distinct public health hazard. The observations of Purdy support those of the author[2] and those of Freeborn.[3]

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[1] Purdy, W. C., 1920. Biological investigation of California rice fields relative to mosquito breeding. U. S. Public Health Reports, Vol. 35, No. 44, pp. 2556-2570.

[2] Geiger, J. C., and Purdy, W. C., 1919. Experimental mosquito control in rice fields. Journ. Amer. Med. Assoc., Vol. 72, pp. 774-779.

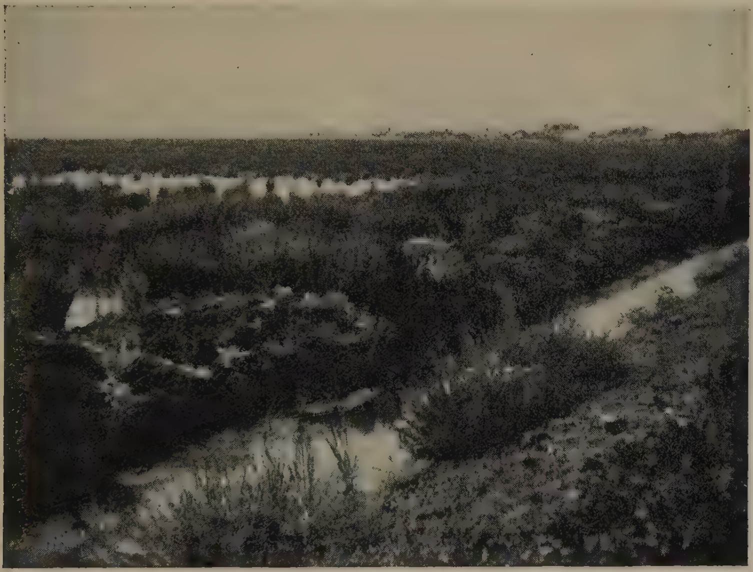

FIG. 102.—Showing a rice field with roadside seepage ditch in which mosquitoes breed.

The explanation for the differences in production is probably in the soil conditions, i.e., where the rice fields are underlaid with an impervious subsoil little water needs to be added during the summer to replace the loss from evaporation and a condition of stagnancy is produced which is unfavorable to Anopheles mosquitoes, while in other localities, such as Anderson, the soil is so porous that much fresh water must be added to keep the required depth with the result that conditions are maintained which favor the anophelines.

[1] Purdy, W. C., 1920. Should rice raising be prohibited near towns? California State Bd. of Health Mo. Bul., Vol. 16, No. 5, pp. 78-81.

[2] Herms, W. B., 1916. Malaria mosquito control. Special Bull. No. 9 (2d ed.), Calif. State Board of Health, 20 pp.

[3] Freeborn, S. B., 1917. Rice fields as a factor in the control of malaria. Journ. Econ. Ento., Vol. 10, pp. 354-359.

The initial steps of all new industries are often characterized by hasty, haphazard methods, practiced in order to insure quick returns at a minimum expense, with little thought regarding efficiency and future results. The rice industry in California is no exception to this rule. Already, the disregard of proper agricultural tenets, such as crop rotation, seed selection, etc., is being felt by some growers. Haste and carelessness are extremely evident in the construction of the irrigating systems. These for the most part are anything but watertight and the inevitable result is that the surrounding country is often converted into a veritable bog. In most of the rice districts the entire countryside is dotted with stagnant pools, the roadsides are bordered and in some places actually covered by stagnant water which is, almost without exception, furnishing breeding grounds for myriads of mosquitoes. It is a conservative estimate that more than one-half the increase of mosquitoes due to rice culture can be traced to such situations as these that are largely due to neglect and could be wholly corrected.

The breeding of mosquitoes in the seepage and drainage pools outside the rice fields is, however, inexcusable. In the first place, careful and efficient irrigation construction would do away with these pools almost entirely, except where the water has been raised to the surface, and, secondly, those pools that would not be eliminated by such construction could easily be cleaned up by draining them to a running stream or filling in the depressions that harbor them. All these expedients failing, surface oiling will kill all the larvæ that happen to be present. With these secondary pools cleared up, certainly 50 per cent of the mosquitoes of the rice-field districts will be eliminated. The water is not turned into the rice fields permanently much before June 1. The mosquitoes of the district, however, have been breeding in other available places since March or some time earlier. Every mosquito destroyed previous to the flooding of the rice field means the cutting off of its countless progeny that would otherwise breed undisturbed in the flooded areas. Again, at the end of the season, the mosquitoes continue to breed for a month or two after the water is drained off the fields, depositing their eggs in neglected pools. In this way, the adults that overwinter and start the next summer's crop are produced. It seems plain that if an ardent anti-mosquito campaign were waged before and after the water is on the rice fields, the numbers left to start the rice field generations would be greatly reduced.

It is out of the question to apply any larvicide to the water used for irrigation. Oil would injure or kill the rice as well as the mosquito wrigglers. Salt applied in quantities large enough to kill the larvæ would not only cut down the rice yield to such an extent as to make its production unprofitable but it would render the land too salty to be of use for any other crop. Rice experts claim that standing water is absolutely essential in spite of some of the claims of the proponents of the merely moist soil idea. Experiments conducted in California show that the former are indeed correct. Vegetable powders that can be used as larvicides are too expensive. Among the natural enemies, fish and dragon flies seem to be the most important, but although they undoubtedly exercise some check, they are handicapped by the rice field conditions to such an extent that their influence may be of little importance.

As has already been mentioned, the malaria-bearing mosquitoes will travel but a few hundred yards from their breeding places and seldom bite except at night or approaching dusk. Thus it will be seen that malaria prevention demands that those people whose residence or occupation takes them into the rice country at night or at dusk should depend on personal protection by veils or screened dwellings, in conjunction with careful quinin prophylaxis as a precaution against accidental bites.

Many communities a mile or more away from the nearest rice fields have stoically accepted the mosquitoes that infested their dwellings as a product of the rice fields and calmly ignored the breeding places that abounded on every hand. The observations already made by other observers and confirmed hundreds of times on the northern California mosquito survey are that it would be highly improbable that any of these communities (those a mile or more from the rice fields) would be bothered greatly by mosquitoes of rice field origin, as they receive their quota of mosquitoes from near-by sources.

Cost of Mosquito Control.—The cost of mosquito control will naturally vary widely for different localities, and in many places the cost might be prohibitive. The value of the property involved, the amount of malaria present, the economic status, potential capacity and number of persons inhabiting the infested area are all matters to be considered. For example, the Anderson (Calif.) campaign above mentioned involved valuable agricultural land, an earnest population and a considerable investment, all threatened by a very high malaria incidence which of course rose with the increase of population and expansion of irrigation. The first cost of control was estimated at $10,000, the area to be placed under control about four square miles, and the population about one thousand. At the end of the season the following table[1] (see Table IV, p. 182) of costs was obtained:

In order to understand the above table it is necessary to state that the average price paid for day labor was $4.50 for an eight-hour day and for teams of two horses, $3.00. For superintendence an addition of 11 per cent should be made to all estimates. Also wherever it was possible teams were used on account of the marked resulting economy.

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[1] Prepared by Professor S. B. Freeborn and M. E. Franklin who were in charge of this campaign.

TABLE IV

Showing Cost of Different Ditching Operations

Method	Type of Ground	Size Depth and Width	Cost per Lineal Foot	Cost per Cubic Yard	Man Hours per Lineal Foot
Hand	Water, grass, clay	1 x 2	.08	1.09	.14
	Soft muck	1 x 1.5	.02	.60	.04
	Water and mud	1 x 1.5	.06	1.09	.11
Plow and Hand..	Wire grass, rocks and gravel	1 x 1.2	.03	.66	.55
	Blue clay	1 x 1.2	.045	1.09	.08
Chain Scraper...	Gravel and clay	4 x 6	.55	.51	.84
Plow and Scraper	Heavy muck, under water	1 x 4	.14	.98	.25
	Wet gravel and clay	1.5 x 6.5	.17	.51	.30
	Gravel and clay	2 x 3	.18	.85	.32
	Dry hardpan	2.5 x 3	.26	.68	.37
	Heavy muck	2 x 2	.14	.98	.25
Plow and Ditcher	Wire grass, wet clay	1 x 1	.017	.46	.03
	Stony loam and wire grass	1 x 1.5	.022	.40	.04
	Dry dirt	1 x 2	.016	.22	.03
	Dry dirt	1 x 2.5	.022	.24	.04
	Swail, muck, grass	1 x 2.5	.023	.25	.04
	Gravel creek bed	1.5 x 2.5	.031	.307	.05

Where the method column indicates that hand labor is used the multiplication of the number of feet of ditch to be constructed by the factor in man-hours per lineal foot will give the approximate number of hours for a single man to complete the contemplated work. Where the method column indicates that horse-drawn tools are utilized, the time for completion can be computed in the same way if, for every five men used, it is understood that three teams of horses are employed.

In order to make it possible to work with teams along swales or other wet areas where the teams would "bog down" an "evener" sixteen feet long was used with one team on each end and to the middle of which the plow or ditcher was attached. In using a scraper in situations such as this or where the cut was too deep to drive the teams in and out with ease the scraper was attached to the whiffletree with a ten-foot drag chain. This procedure necessitated the addition to the team crew of an extra man to dump and return the scraper to the ditch to be refilled by another worker there. The normal team crew was composed of three men if working alone, but in combination of three teams which was found most economical, five men were sufficient to keep the teams working at the highest efficiency.

The general procedure of forming the ditches varied with the type of work the ditches were expected to do. In large seepage areas the general practice was to "Herring bone" the area with plow furrows to take off the surplus water, and after a week or two when the ground had become firmer the furrows that were still gathering seepage were widened, run to grade and cleaned with a ditcher and the banks on each side cleaned by hand of vegetation for a distance equal to the depth of the ditch. The furrows that had dried out during the interim were closed in by hand. In cases where the ditch to be constructed was located in the center of a swale or well-developed water course, a plow attached to the "evener" mentioned above was run along the line of the proposed ditch and again after this furrow had allowed for sufficient run-off, a ditcher attached in the same way was used to widen, deepen and smooth off the sides. The only remaining type of ditch to be considered is the new ditch through dry land that is used as a connecting link for different drainage areas or as a diverting ditch. For the most part these ditches were constructed by alternating trips of the plow and ditcher, starting at the outer edges of the ditch and working toward the middle thus leaving a bank in the center to work against until the ditch was nearly completed. Ordinarily a 16-inch blade plow was sufficiently heavy to do this work, but occasionally in cases where extremely heavy sod or hard pan was encountered. it was necessary to use a pavement plow. In ditches running deeper than two feet it is impossible to obtain very satisfactory results with the ditcher after that depth is reached. At this depth it is advisable to remove the broken-up dirt from the ditch by means of scrapers. The effect of the depth upon the cost per cubic yard is of very slight significance until the ditch reaches the two-foot level. The cost per cubic yard for removing dirt below the two-foot level then increases about 10 per cent per foot in depth until the four-foot depth is reached where the cost increases approximately 12 per cent per foot to the six-foot depth. Below this level the increased cost becomes more marked yet, due to the multiple handling of the dirt and the necessity for pumping out the water that is generally encountered.

In the table there is included a column headed "Man-hours per lineal foot." This factor was obtained by dividing the number of feet of ditch of each type by the number of hours of labor actually expended thereon, or what is more practical, the number of hours of labor actually paid for on each one of these types. The only reason for including this item is that it might act as an index on the time required to construct certain sizes of ditches under given conditions.

As labor and teams are almost the only factor to be considered in construction, it is possible to establish a constant which, if multiplied by the cost per lineal foot, will give the man-hours per lineal foot. Reversely by dividing the man-hours per lineal foot by the same constant the relative cost per lineal foot may be established. This constant in the table proved to be 1.8, but would, of course, vary with the prices paid for labor, increasing with decreased wages.

Where teams were used the apportionment of costs averaged 80 per cent for labor, 16 per cent for teams, and 4 per cent for incidentals. If hand labor alone was used the labor averaged to cost about 97 per cent of the total with 3 per cent for incidentals. In considering hand labor it is well to state that it was found most economical to work men in crews of six or eight and never in groups smaller than the number of kinds of implements used regularly. To illustrate this point, on one watercourse it was necessary to first cut out the tule with a scythe, grub out the roots with a mattock and deepen with shovels. Three different laborers were alternately placed in this location separately and the cost remained constantly at from 35 to 42 cents per lineal foot. Shortly after this the same three men and one additional laborer were put on the same ditch together using a scythe, a mattock and two shovels and the cost dropped to 14 cents per lineal foot and remained there until the ditch was completed. The reason for this is probably a combination of several factors, the unintentional competition between the mower and the grubber and between the grubber and the shovelers, as well as the elimination of the rest periods that invariably take place each time the solitary worker changes tools.

TABLE V

SHOWING COST OF OILING

		PER CENT TOTAL OILING EXPENSE
Cost of labor per 8-hour day	@ $4.25–$4.50	51
Cost of teams of one horse and wagon	@ 2.00	8
Cost of oil — fuel oil — 27 + B	@ .10 per gal.	28
Cost of incidentals, pumps, boots, tools, repairs		12

Gallons oil per acre of breeding ground	10.5 gallons
Cost per acre to treat (total cost)	$3.67

	COST PER ACRE	PER CENT
Labor	$1.88	51.2
Oil	1.05	28.6
Transportation	.30	8.1
Supplies and incidentals	.44	11.9
	$3.67	99.8

Cost per gallon to apply oil (including oil)	$ .35
Time of application per gallon	15 minutes
Gallons of oil applied per day per man	32 gallons

The organization of an oiling crew differs with the type of ground to be covered. In California, where the mosquito-breeding water is largely permanent throughout the season, i.e., not subject to flooding and drying through intermittent rains, it is not necessary to employ permanent inspectors to precede the oilers as one thorough primary inspection early in the season, supplemented by casual checking on the part of the superintendent and observations by the oilers, will suffice. Where it is necessary to employ inspectors 20 per cent should be added to the labor expense and 14 per cent to the total cost per acre.

The best arrangement that we have used has been two men and a one-horse team on which a hundred-gallon drum of oil could be mounted. Providing that not more than 5 per cent of the territory concerned needs the application of oil and the wet areas are about evenly distributed over the entire district, one unit of this kind can easily handle eight square miles, applying an oiling to all pools on an average of one in two or three weeks.

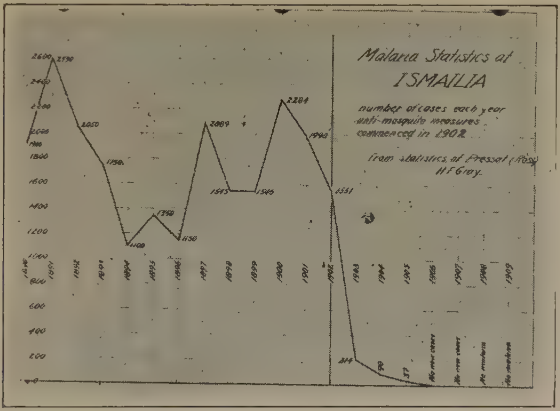

FIG. 103.—Curve showing reduction of malaria at Ismailia (Suez Canal) with the application of anti-mosquito measures in 1902.

It is interesting to note that although an oiler by continuous pumping can empty one of the five-gallon knapsack spray pumps (Myers) in twenty minutes, the average speed maintained in the field counting the entire time for which the men were paid was four gallons per hour. This is not a commentary on modern labor conditions for the oilers setting this record were equal, if not superior, to the average workman.

Malaria Reduction as the Result of Anti-mosquito Measures is nicely shown by the following table (Table VI) after Cassa:[1]

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[1] Cassa, Jorge Le Roy Y., 1913. Sanitary Improvement in Cuba as demonstrated by statistical data. Amer. Journ. of Public Health, No. 3, Vol. III.

TABLE VI

Showing Deaths from Malaria in Havana from 1871 to 1911 Inclusive

The enormous reduction in deaths will be seen to begin with the inauguration of anti-mosquito measures in 1901.

Years	Total Deaths	Death Rate	Years	Total Deaths	Death Rate
1871	262	1.33	1892	286	1.33
1872	316	1.60	1893	246	1.12
1873	329	1.61	1894	201	0.90
1874	288	1.45	1895	206	0.90
1875	284	1.43	1896	450	1.95
1876	334	1.68	1897	811	3.48
1877	422	2.12	1898	1907	8.00
1878	453	2.28	1899	909	3.76
1879	343	1.72	1900	325	1.30
1880	384	1.93	1901	151	0.55
1881	251	1.26	1902	77	0.29
1882	223	1.12	1903	51	0.19
1883	183	0.91	1904	44	0.16
1884	196	0.98	1905	32	0.11
1885	101	0.50	1906	26	0.08
1886	135	0.67	1907	23	0.08
1887	269	1.34	1908	19	0.06
1888	208	0.99	1909	6	0.01
1889	228	1.11	1910	15	0.05
1890	256	1.23	1911	12	0.03
1891	292	1.37			

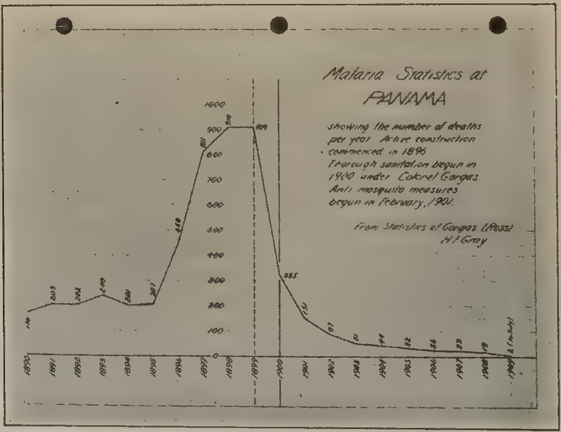

Fig. 104.—Curve showing reduction of malaria at Panama (Panama Canal Zone) with the application of anti-mosquito measures in 1901.

Figs. 103 and 104 show graphically the results of anti-mosquito work at Ismailia and at Panama.

Results Obtained in Combating Yellow-fever Mosquitoes.—The table taken from Doane,[1] shows the death rate in Havana due to yellow fever from the years 1893 to 1902 inclusive; the work of the Yellow Fever Commission based on mosquito control having been put into effect in 1901 and 1902. Surely this table (Table VII) is eloquent in its praise of this splendid work.

TABLE VII

DEATHS IN HAVANA FROM YELLOW FEVER DURING YEARS 1893 TO 1902 INCLUSIVE

	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902
January....	15	7	15	10	69	7	1	8	7	0
February....	6	4	4	7	24	1	0	9	5	0
March......	4	2	2	3	30	2	1	4	1	0
April.......	8	4	6	14	71	1	2	0	0	0
May........	23	16	10	27	88	4	0	2	0	0
June........	69	31	16	46	174	3	1	8	0	0
July........	118	77	88	116	168	16	2	30	1	0
August.....	100	73	120	262	102	16	13	49	2	0
September...	68	76	135	166	56	34	18	52	2	0
October.....	46	40	102	240	42	26	25	74	0	0
November...	28	23	35	244	26	13	18	54	0	0
December...	11	29	20	147	8	13	22	20	0	0

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[1] Doane, R. W., 1910. Insects and Disease. Henry Holt & Co., New York, pp. xiv + 227.

CHAPTER XII

BUFFALO GNATS AND HORSEFLIES

A. Buffalo Gnats

Order Diptera, Suborder Nematocera, Family Simuliidæ

Adult Characteristics.—The family Simuliidæ includes the insects commonly known as buffalo gnats, black flies, sandflies, and turkey gnats. They are small (1 to 4 mm. long) blood-sucking flies, with blade-like piercing mouth parts in the female, but more or less rudimentary in the male. The thorax presents a strong development of the scutum and reduction of præscutum resulting in a prominent hump. The antennæ are eleven-jointed, the eyes of the female are distinctly separated (close together and prominent in the male), palpi four-jointed, wings broad and iridescent, the venation being characterized by a strong development of the costal veins (Fig. 105).

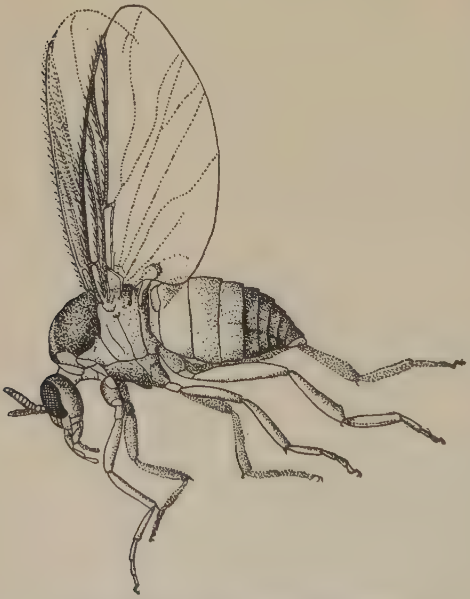

Fig. 105.—A buffalo gnat, *Simulium pecuarum.* (Redrawn after Garman.)

Life History. — Buffalo gnats often occur in enormous swarms in certain localities during late spring and early summer causing great annoyance to stock and human beings. Fruit picking and other labor is made very difficult in some sections because of the insidious attacks of these tiny persistent gnats in spite of gloves and veils. The gnats are of aquatic origin.

Although running water is favored as a breeding place, such as shallow mountain creeks, the gnats may also breed in roadside ditches of more slowly moving water. The gnats may be found in numbers a mile or two from water probably in search of food. The eggs are deposited in masses on dipping leaves, twigs, grasses and water-splashed rock surfaces and timbers. Comstock says he has often watched the gnats hovering over the brink of a fall where there was a thin sheet of swiftly flowing water, and has seen them dart into the water, and out again. At such times he has always found the surface of the rock more or less thickly coated with eggs, and has no doubt that an egg is fastened to the rock each time a fly darts into the water.

The time required for hatching is from 10 to 30 days, depending on temperature. The newly emerged larvæ attach themselves to submerged objects, such as stones, logs, etc., by means of silken threads. Movement from place to place is gained by shifting their anchorage. In some favorable location, such as the riffles on the downstream side of an old log partially damming a little stream, there may be thousands of these tiny spindled larvæ. The larvæ as well as the pupæ being provided with gill filaments remain submerged. The larval period of some species is said to require but 4 to 5 weeks. In some species the winter is passed in the larval stage, giving rise to but one generation in a year. The food of the larvæ consists of small crustacea, protozoa and algæ.

The pupal period is quite short in some species, requiring not over 5 or 6 days, while still others evidently require nearly a month. It is also true that temperature influences this stage, i.e., cooler weather retards the emergence of adults.

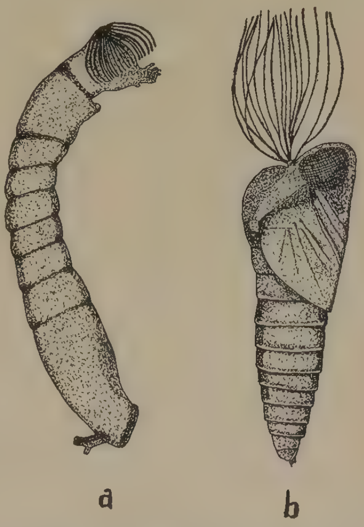

FIG. 106.—(*a*) Larva and (*b*) pupa of Simulium; latter removed from cone-shaped cocoon. (Redrawn after Lugger from Washburn.)

Larvæ.—The brown to whitish larvæ are cylindrical, twelve-segmented, slightly thinner in the mid-region and when fully grown are from 10 to 15 mm. in length (Fig. 106a). The posterior end of the body is provided with a toothed disk-like sucker, composed of two modified parapodia. The anterior proleg is also modified into a prehensile toothed disk. By means of this organ, the larva moves from place to place with a looping motion. Through the agency of a secretion from the salivary glands, the larvæ are able to spin a silken thread to which they attach themselves, hanging from the end of the thread or moving along its length, the thread being attached to rocks or other débris.

Although the larvæ are provided with a well-developed tracheal system, there are no open spiracles, and respiration is carried on by means of gills, recognized as branched retractile structures located dorsally on the last abdominal segment. The fan-shaped filamentous structures located on the head are for the purpose of creating a current by means of which food is drawn to the mouth.

Pupæ.—When the larvæ are ready to pupate each spins a crude pocket-like cocoon open at the upper end. The pupæ are provided with respiratory filaments attached anteriorly to the dorsal portion of the thorax. The filaments are often quite numerous and because of their constancy in number in a given species are looked upon as diagnostic characters (Fig. 106b).

The Bite.—There is perhaps no other insect of equal size that can inflict so painful a bite as can the buffalo gnat. The mouth parts are of the Dipteron type, consisting of six blade-like lancets.

Human beings as well as domesticated animals are viciously attacked. The eyes, ears, nostrils, wrists and all exposed parts of the body are subject to attack. The extreme pain and the resultant local swelling, and occasionally complications, indicate the introduction of an active venom.

Losses due to the bite of this fly are estimated variously by stockmen. Washburn[1] states that "in 1884, in Franklin's Parish, Louisiana, they killed 300 head of stock in a week. In 1874 the state of Tennessee alone lost as much as $500,000 worth of stock from the attack of these flies."

Relation to Disease.—Owing to the intermittent blood-sucking habits of the buffalo gnats, it has long been suspected that these insects might play a part in the transmission of disease, but as a matter of fact, little experimental evidence is at hand to verify this suspicion. Since *anthrax* is comparatively easily transmitted from animal to animal, inasmuch as *Bacillus anthracis* is both exceedingly virulent and long-lived, it may be supposed that this disease could be transmitted, if any, but even here experimental evidence is wanting.

Since the rather startling statement of Dr. Louis W. Sambon[2] in 1910, referring the transmission of pellagra to a buffalo gnat, the study of Simuliidæ with regard to disease transmission has taken new impetus. The gnats, however, have evidently no relation to this disease. Pellagra has been carefully studied by the United States Public Health Service, and in the Public Health Reports of October 23, 1914, Goldberger states that Pellagra is neither infectious nor contagious, that it is essentially of dietary origin, dependent on some yet undetermined fault in diet, and that the disease does not develop in those who consume a mixed, well-balanced and varied diet.

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[1] Washburn, F. L., 1905. Diptera of Minnesota. University of Minnesota Agr. Exp. Sta., Bull. No. 93.

[2] Sambon, L. W., 1910. Progress Report Investigations of Pellagra. Journ. of Tropical Medicine and Hygiene, Vol. XIII, No. 19.

Gnat Control.—Knowing the breeding habits of the buffalo gnat, it will be appreciated that its control is a difficult task. The writer has repeatedly recommended that streams in which these insects are breeding should be kept as free from débris as possible, including dipping branches of overhanging trees and submerged roots. It is possible to do this in the immediate vicinity of communities, but prevailing winds may after all bring swarms of gnats from a distance. At all events the removal of débris from streams lessens the opportunity for them to deposit their eggs. Old logs lying crosswise of a stream are a particular menace because shallow waterfalls are thus usually produced, hence affording ideal breeding places for the gnats. The fact that the larvæ tend to congregate in masses in the swifter parts of streams in which they are breeding makes it possible to remove them in quantities when once located.

To prevent annoyance to beasts of burden some form of spray or ointment may be applied. While many repellents are on the market, few are of any benefit and practically none affords absolute relief. Any mixture containing fish oil is of some benefit, but must be applied daily. (See also under Horn fly.) Smudges act as good repellents, especially burning pyrethrum powder or buhach. Oil of citronella applied to the skin and face effectually keeps the insects away as long as the parts remain moist with the oil.

Systematic.—The family Simuiidæ according to most authors consists of but one genus, Simulium, however, Malloch[1] has raised Roubaud's subgenus Prosimulium to generic rank. The best-known and most widely distributed species in America is *Simulium pecuarum* Riley, the buffalo gnat. Riley's description is here given as abbreviated by Garman:

> "*Male.*—Eyes meeting and with two sets of facets. Mouth parts soft. Head black. Antennæ black, with some red. Maxillary palpi black. Thorax black above. Abdomen black, with grayish white posterior margins to segments.
>
> "*Female.*—Eyes not meeting. Head gray slate, with short yellow hairs. Eyes black, with coppery or brassy reflections. Antennæ black with whitish pubescence. Thorax grayish slate and generally distinctly marked with two mediodorsal and two subdorsal longitudinal black bands. Under side of thorax, grayish slate. Abdomen with a broad gray longitudinal band from near the base of the second segment, where it is broadest."

Simulium venustum Say is the black fly, a widely distributed species extending from Canada to Texas and from Florida westward. Say's description is as follows:

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[1] Malloch, J. R., 1914. American Black Flies or Buffalo Gnats. U. S. Dept. of Agric., Bur. of Ento. Tech., Series No. 26, 72 pp. and VI plates.

"Black: thorax, two perlaceous spots before and a larger one behind; poisers black; capitulum bright yellow, dilated.

"Body black; wings whitish, with yellow and iridescent reflections.

"*Male,* eyes very large, separated only by a single line, dull reddish yellow, inferior half black; thorax velvet black, a bright oblique, perlaceous, dilated line each side before, and a large perlaceous spot or band behind; sides beneath varied with perlaceous; feet, tibia above, and first joint of the four posterior tarsi white; abdomen with an oblique perlaceous line at base, and two approximate, lateral, perlaceous ones near the tip.

"*Female,* eyes moderate, thorax plumbous-black, immaculate, scutellum black, abdomen whitish beneath."

Simulium meridionale Riley is the turkey gnat, which also enjoys wide distribution coinciding with the buffalo gnat. This species attacks chickens and turkeys, biting the combs and wattles, and is said to produce symptoms similar to cholera.

Riley's description is given by Garman as follows:

"The male is from 1.5 to 2 mm. in length, the eyes meeting above, where the facets are coarser and of a brilliant coppery luster, those on the ventral side smaller and black. Thorax dense black with bluish luster, ventral side grayish. Legs reddish with black tarsi. Abdomen above black, posterior margin of segments edged with gray. Ventral sides of segments two and three light reddish gray, the rest blackish with gray posterior margins."

The female is described as from "2.5 to 3 mm. long; the head slate-blue, with silvery pubescence; the thorax, with three longitudinal lines, the median narrow and widening at the apex, the outer curving in at the base and out at the apex; beneath slate-blue; abdomen with last five segments dark blue above; segments 2, 3 and 4 each with a black cross bar; segments 5, 6 and 7, with two submedian stripes, disappearing on 7; bluish white everywhere beneath; legs brownish black."

B. HORSEFLIES

Order Diptera, Suborder Brachycera, Family Tabanidæ

Characteristics.—To the family Tabanidæ belong certain biting flies commonly called horseflies, gadflies and deer flies. The males do not bite but feed on flowers and vegetable juices. All the members of this family consist of large flies (10-25 mm.), the body being heavy and the head possessing very large eyes. In the female the eyes are widely separate (dichoptic), while in the males the eyes are contiguous (holoptic). The antennæ (Fig. 28) are generally short (Brachycera) and porrect, consisting of three joints, the third joint being annulated; the arista is absent. The wing venation (Fig. 17) is simple and characteristic.

The *larvæ* (Fig. 107) are elongate and cylindrical, tapering at both ends; with well-developed head; body eleven-segmented, each

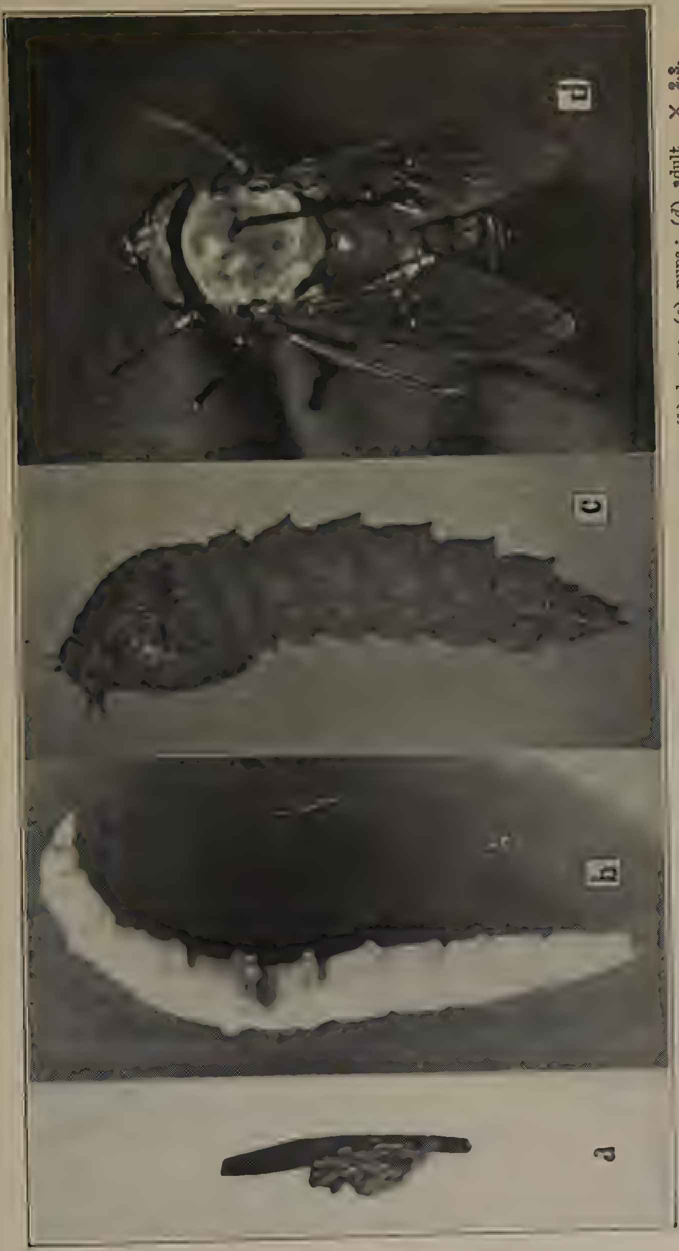

FIG. 107. Showing life history of a typical horsefly (Tabanus). (*a*) egg mass; (*b*) larva; (*c*) pupa; (*d*) adult. × 2.3.

segment except the first three and last is provided with a fleshy ridge with parapodia which aid in locomotion. The terminal segment bears a pair of stigmal openings and is somewhat prolonged to form a breathing tube. They are usually yellowish white to ashy white in color.[1]

The *pupæ* of tabanids resemble lepidopterous pupæ somewhat, rounded anteriorly and tapering posteriorly. In color they are yellowish to reddish brown and are distinctly spiny. The flies escape from the pupal case through a dorsal longitudinal slit.

Breeding Habits and Life History.—The Tabanidæ are aquatic or semi-aquatic in breeding habits. The eggs to the number of two to three hundred are deposited in irregular masses (Figs. 107-109) on marsh or swamp vegetation, for example the leaves of Sagittaria, or on the leaves and twigs of trees (e.g., willows) overhanging ponds or sluggish streams. In the Sierra Nevada mountains horseflies occur in great numbers at elevations of 8,000 to 9,000 feet, where they breed in the soggy ground produced by springs and water from the melting snow. Deer and other wild animals suffer terrible torment in the summer time in such localities from the bites of horseflies.

The eggs, covered with a protective secretion, are deposited in early and late summer. The larvæ hatch in from 5 to 7 days, depending on the species, the larger forms requiring somewhat more time than the smaller ones. The larvæ on hatching fall to the ground or surface of the water, penetrate the surface film and then drop to the bottom, or if there is no water, the larvæ burrow into soft mud. Moisture is certainly necessary for their development. Insect larvæ such as tipulids, also crustaceans, earthworms and other soft-bodied animals provide food for these voracious, carnivorous creatures; cannibalism is also practiced. They are commonly encountered along the edges of marshy ponds among the débris, and in roadside ditches, overflow from rice fields and even in the edges of salt marshes where they may occur in great abundance. The larvæ grow rapidly during the rest of the summer and autumn, and very slowly, if at all, during the winter in the single brooded species, attaining full growth in early spring, crawling out of the softer wet mud and into drier earth, where they pupate. The pupal period requires from two to three weeks. Where there is more than one brood a year, the second brood overwinters in the larval stage. The emerging flies take refuge among the foliage of near-by trees and the females soon begin attacking warm-blooded animals. The males do not suck blood, but feed on nectar and other plant juices. Unless swept up with an insect net in grass and other vegetation the males are seldom seen.

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[1] The attention of the student is directed to a splendid account of the "Early Stages of Tabanidæ" by Werner Marchand in the Monographs of the Rockefeller Institute for Medical Research No. 13 (Nov. 15, 1920), 203 pp. and 15 plates.

Bites.—The horseflies have broad blade-like mouth parts (Fig. 28) by means of which a deep wound is cut, causing a considerable flow of blood. The bite is painful and owing to the intermittent habits of the flies there is great danger from infection.

In describing an outbreak of gadflies in Kentucky, Garman has the following to say: [1]

> "Beef cattle had lost an average of 100 pounds as a result of the constant annoyance from them. . . . On cattle I counted from ten to ninteen. On mules and horses in harness they were a constant annoyance and even hogs were not exempt. Seven of the flies were counted on the exposed side of one of these animals lying in a puddle.
>
> "The persecuted stock appeared to have given up fighting their enemies and allowed them to have their way. The switch of a cow's tail was observed to pass over the backs of clinging flies without causing them to move. . . . During the middle of the day animals suffered so much that they refrained from grazing at all, either standing close together about the barn or else lurking singly in thickets or standing in pools formed by small streams."

Relation to Anthrax.—The horseflies are decidedly intermittent in their biting habits, and inflict a definite lancet-like prick from which blood exudes so that the proboscis becomes soiled. The flies will bite sick animals as well as healthy ones,—hence the possibility for the transmission of an infectious blood disease seems to exist. It is regrettable that so little experimental evidence is at hand; however, anthrax is at once thought of, owing to the virulence and hardiness of the causative bacillus.[2]

Anthrax, also known as malignant pustule or carbuncle, wool sorter's disease, charbon (French), is caused by *Bacillus anthracis.* Nearly all species of domesticated animals and man are susceptible; the herbivora and rodents are most liable to infection. The mortality may be as high as 70 to 90 per cent.

After the introduction of the organism into the animal the incubation period is exceedingly short, i.e., from three to six days. The bacilli are seen in the blood stream in advanced cases as chains of rod-shaped bodies (Fig. 108).

Entrance to the body is gained mainly in one of three ways, 1st, through lesions or pricks, i.e., *inoculation,* producing local anthrax or malignant pustule; 2d, by *inhalation* of the spores, producing pulmonary anthrax; and 3d, by *ingestion* with food, producing intestinal anthrax.

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[1] Garman, H., 1910. An outbreak of gadflies in Kentucky. Kentucky Agricultural Exp. Sta., Bull. No. 151.

[2] Mr. M. B. Mitzmain has verbally informed the writer (Feb. 17, 1914) that he has successfully transmitted anthrax from artificially infected guinea pigs to healthy guinea pigs through the agency of both *Tabanus striatus* and *Stomoxys calcitrans.* A preliminary account of these experiments is in the Journal of Tropical Medicine and Hygiene (London), Vol. XVII, No. 4.

Manifestly horseflies could only relate directly to the first mode of infection (inoculation), but it is not altogether improbable that an epidemic of anthrax may thus be started and assisted in spreading. Nuttall cites Bollinger (1874), who captured horseflies on a cow dead from anthrax and saw the bacilli in preparations made from the stomachs and intestines of the insects. Two rabbits inoculated therewith died of anthrax.

Instances are recorded in which apparently the simple bite of the infected fly was all that was needed to produce malignant pustule in humans. Several physicians have related instances to the writer in which this was said to have occurred, notably one case in which a man was in the act of burying a cow dead of anthrax when he was bitten severely in the back of the neck by a horsefly and in due time developed a malignant pustule. Nuttall also cites a number of similar instances.

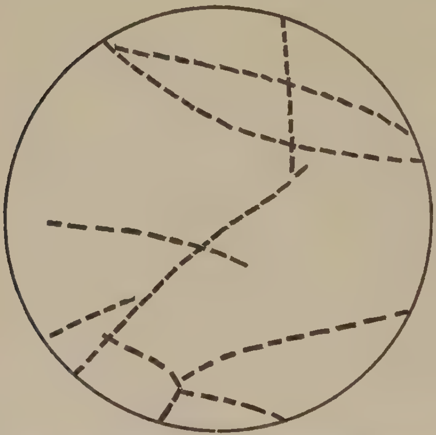

FIG. 108.—*Bacillus anthracis*, causative organism of anthrax. (Greatly enlarged.)

Relation to Surra.— Surra is a highly fatal disease of horses and other susceptible animals, such as the carabao, which latter may evidently become chronic carriers. Guinea pigs and monkeys are also highly susceptible. The disease is endemic in the Philippine Islands, southern Asia, Korea and Madagascar. The causative organism is *Trypanosoma evansi* Steel which resembles the trypanosome of Nagana very closely, as do the symptoms, i.e., there is fever, edema of the abdomen and genitalia, marked depression and emaciation. The trypanosomes are found in the blood and especially the lymph swellings from the beginning of the first symptoms. The incubation period is from eight to nine days.

Mitzmain[1] has been successful in transmitting the disease from animal to animal through the agency of a horsefly, *Tabanus striatus* Fabr. (Fig. 109).

In a series of experiments in which *Tabanus striatus* was used, he allowed the flies to first bite an infected guinea pig or horse for not more than one minute, usually forty-five seconds, and then transferred them to a healthy animal where they were allowed to complete the meal without interruption. An interruption of five seconds to three minutes was necessary to transfer the flies from animal to animal. The horses and mule employed in these experiments were kept in a screened stable for from six to eight months previous, and the monkeys, guinea pigs and rabbits in fly-screened cages for about ninety days. In all cases the animals were examined frequently (blood examinations made) and declared surra free at the time the experiments began.

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[1] Mitzmain, M. B., 1913. The mechanical transmission of Surra by *Tabanus striatus* Fabricius. Philippine Journ. of Sci., Vol. VIII, No. 3, Sec. B., pp. 223-229.

Flies bred from eggs were allowed to bite a guinea-pig which had been inoculated with blood from a carabao which had been infected with surra for nearly a year previous to the experiment. Three flies were applied individually in tubes to the surra-infected guinea-pig and allowed to feed from forty-five seconds to one minute and thirty seconds, after which they were transferred to a monkey and allowed to feed until satisfied, i.e., from five to twenty-one minutes. The first high temperature, 40.1° C., occurred on the eleventh day, accompanied by a few trypanosomes in the peripheral circulation, increasing in numbers until the death of the monkey on the twenty-fifth day.

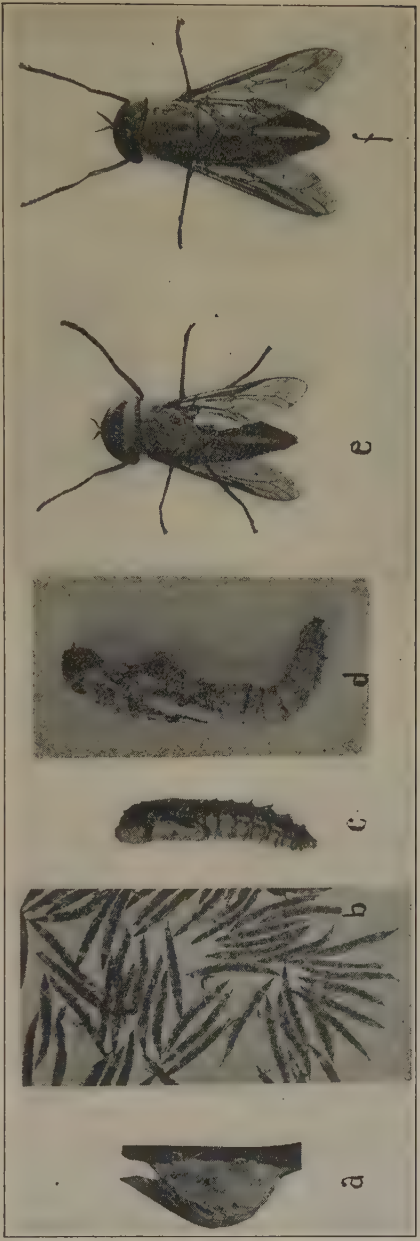

Fig. 109.—Life history of *Tabanus striatus*, a carrier of surra in the Philippine Islands. (*a*) egg mass; (*b*) a group of larvæ; (*c*) pupa; (*d*) imago emerging from pupa case; (*e*) adult male; (*f*) adult female. (Photo by Mitzmain.) × 2.

Blood from the heart of this monkey was inoculated into a horse and two guinea-pigs. The latter showed infection on the eighth and ninth days respectively, and the horse on the seventh day. Two flies were permitted to bite this horse, the insects being interrupted in their biting in from forty to forty-five seconds and then transferred to a healthy horse where the feeding was completed. This animal showed numerous trypanosomes in its circulation on the ninth day. Thus positive results were secured in both a monkey and a horse.

Blood from this newly infected horse was inoculated into a mule, two monkeys and two guinea-pigs, all of which became infected in due season, both monkeys dying on the fourteenth and fifteenth days respectively.

A second series of experiments was carried on with captured flies, which were allowed to bite the above-mentioned surra horse and later a healthy horse, similar feeding methods being observed. This experiment also proved positive, as did blood inoculations to monkeys and guinea-pigs.

In order to eliminate the possibility of hereditary transmission of trypanosomes in the flies a further experiment was conducted, in which seventy-four flies, hatched from eggs of a fly which had previous to egg deposition fed on a surra monkey, were allowed to bite a healthy monkey during a period of two weeks with negative results.

Mitzmain concludes that the "contaminated labellum of the fly does not appear to be a factor in the conveyance of infection. The maximum length of time that *Trypanosoma evansi* has been demonstrated microscopically in the gut of this species of fly after feeding on infected blood is thirty hours; the organisms were found in the fly's dejecta two and one half hours after biting the infected animal; and suspension of flies, when injected subcutaneously, were found infective for animals for a period of ten hours after the flies had fed on infected blood."

In a letter to the writer under date of November 18, 1913, Mitzmain states that "infection is not transferred by *Tabanus striatus* later than twenty minutes after the infective meal. The longest time I have succeeded in inducing flies to transmit was fifteen minutes and all results from twenty minutes to forty-eight hours were entirely negative. This despite the fact that trypanosomes survive in the intestinal tract of *T. striatus* for a period of thirty hours." Mitzmain believes this horsefly to be the principal carrier of surra and that the stable fly, *Stomoxys calcitrans*, is ruled out, which is indeed indicated by the long and careful series of experiments conducted by that worker on both species of flies.

Tularæmia.—In 1919 a disease of hitherto unknown etiology was reported by Francis[1] as deer-fly fever or Pahvant Valley plague. It is later described by the same author[2] and given the name *tularœmia.*

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[1] Francis, Edward, 1919. Deer-Fly Fever or Pahvant Valley Plague. U. S. Public Health Reports, Vol. 34, No. 37, pp. 2061-2062.

[2] Francis, Edward, *et al*, 1921. Tularæmia Francis 1921, a new disease of man. U. S. Public Health Service Bull. No. 130, 87 pp.

It is a specific infectious disease traceable to *Bacterium tularense.* It is a disease of rural populations and occurs during the summer months, coinciding with the prevalence of the vector, *Chrysops discalis* (Fig. 110). "Following the fly bite on some exposed surface of the body (neck, face, hands or legs) the onset is sudden, with pains and fever; the patient is prostrated and is confined to bed; the lymph glands which drain the bitten area become tender, inflamed and swollen, and commonly suppurate, requiring incision. The fever is of a septic type, lasting from three to six weeks, and convalescence is slow" (Francis). The reservoir of infection is said to be in the sick and dying jack rabbits. It is endemic in Millard County, Utah. The fly is probably merely a mechanical vector of the disease as indicated by the experiments of Francis and Mayne (*loc. cit.*). It has also been found that *tularæmia* is carried from rabbit to rabbit by means of the rabbit louse, *Hæmodipssus ventricosus. Cimex lectularius,* the common bedbug, was also found to be a successful carrier in experiments with guinea-pigs, as was the mouse louse, *Polyplax serratus* in the case of white mice.

Trachoma.—That horseflies may be instrumental in the transmission of trachoma has been suggested by Eaton as early as 1908 (Ophthal. Record, Sept., 1908). Eaton has long endeavored to establish a connection between equine conjunctivitis and trachoma in human beings. The writer has listened to an interesting account of this investigation by Eaton himself, but as the latter freely admits there is as yet no proof.

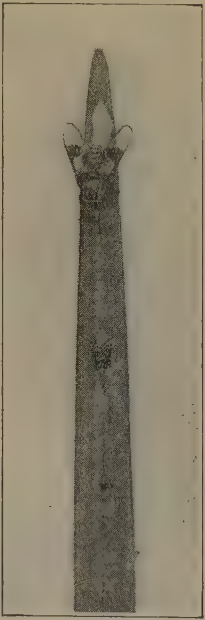

Fig. 110.—A horsefly (Chrysops) in the act of oviposition. Note also an egg mass farther down on the leaf. (Photo by Hine.) × 1.

Filariasis.—The so-called mango fly *Chrysops dimidiata* Van de W. has been shown by Leiper (*loc. cit.*) to be a vector of *Filaria loa* Cobbold. Other species believed to be able to carry are *C. longicornis* Macq. and *C. centurionis* Austin. The larvæ of *Filaria loa* are found in the peripheral blood vessels during the day time, showing a diurnal periodicity which gave rise to the term *Filaria diurna.* The larvæ measure 298 μ in length by 7.5 μ in thickness (Castellani and Chalmers), resembling *Filaria bancrofti* quite closely. In this stage they are ingested by the Chrysops flies and undergo development similar to *Filaria bancrofti* in the mosquito. The manner of introducing the worms into the human host by the insect vector is not well understood.

The adult worms, females measuring from 44 to 63 mm. in length and the males 25 to 34 mm. (Castellani and Chalmers), inhabit the superficial subcutaneous connective tissue and are known to move about from place to place quite rapidly giving rise to transient itching swellings known as Calabar swellings. The parasites have been "noted under the skin of the finger, the back, the breast, the scrotum and penis, the eyelid, under the conjunctiva, the mucosa of the tongue." This form of Filariasis is endemic along the West Coast of Africa.

El debab.—El debab is a trypanosomiasis of Algerian horses and camels traceable to *Trypanosoma berberum* Elmond and Et. Sergent. This disease is evidently spread by horseflies, *Tabanus nemoralis* Meig. and *T. tomentosus* Macq. being considered vectors.

Control.—Inasmuch as the painful bite of the Tabanidæ, especially if these insects are abundant, makes the life of domesticated animals, notably horses, quite unbearable, it is desirable that some repellent substance or mechanical means be employed to prevent injury. Efficient repellents usually contain fish oil, which is disagreeable and in the presence of dust produces a very filthy coat; other materials in use are "dips" and these do not as a rule act for more than a few hours at most. Furthermore, where whole herds of animals are to be treated, this method is impracticable. Horse nets afford considerable relief, and often avert dangerous "runaways."

Comparatively little of a preventive nature has been done, except for the notable work of Porchinski, reported by Howard.[1] Porchinski observed that Tabanids collect in great numbers in the neighborhood of humid spots and lower themselves to the surface of pools to drink, actually touching the water with their bodies. It occurred to him that a covering of kerosene on the water would endanger the lives of the insects as they came in contact with the surface. Hence a quantity of kerosene was applied to a given pool, with most gratifying results. By the third day of the experiment the "pool of death" was covered with "floating islands" of dead Tabanids. Porchinski recommends that a favorite pool be selected, and that the oil be poured on so that a thick uniform layer of oil is formed covering the entire pool. Such "pools of death" apparently attract the Tabanids from over a considerable adjacent area. The oil must of course be applied as early as possible during the season when the adult flies appear and begin to mate and deposit eggs.

Systematic.—The following description of family characters and key to the North American Genera is according to Hine:[2]

"The family Tabanidæ includes medium-sized to large insects commonly called horseflies, gadflies, deerflies, dogflies, earflies and various other names.

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[1] Howard, L. O., 1899. A remedy for gadflies. Porchinski's recent discovery in Russia, with some American observations. U. S. Dept. of Agric., Div. of Entomology, Bull. 20, N. S.

[2] Hine, James S., 1903. Tabanidæ of Ohio. Ohio State Academy of Science, Special Papers, No. 5.

Usually its members are readily recognized at sight by their form and general appearance.

"The three-jointed antennæ with the third joint annulated and without a style or arista, the rather large tegulæ, and the well-developed pulviliform empodia taken together serve to distinguish them from other flies in case of any doubt.

"None of the species are really small; the head is large, larger and hemispherical in the male, smaller and somewhat flattened in the female.

"The antennæ are porrect and composed of three segments of which the third is compound, having five or eight annulations. When there are eight, the basal one is only slightly longer than the others, but when there are five, the basal one is much longer than any of the others, often longer than all the others combined.

"The eyes are separated in the female and contiguous in the male. They have an area of enlarged facets above in the latter sex, and in life are marked with green and purple markings in both sexes. In dry specimens these markings are lost, but may be partially restored by moisture. Ocelli are present in some species and absent in others; and the occiput is flat or concave. The proboscis projects and in some species is much elongated; the maxillary palps are large and two segmented.

"The thorax and abdomen are clothed with more or less hair, but no spines or bristles. The wings are rather large and encompassed by the marginal vein, two submarginal and five posterior cells present, basal cells elongate, anal cell usually and sometimes some of the posterior cells closed. Tegulæ always prominent. Legs ample; pulvilli moderate; empodia developed pulviliform; middle tibia with spurs at the tip.

"Abdomen composed of seven visible segments, broad, never constricted."

KEY TO THE NORTH AMERICAN GENERA OF TABANIDÆ
(after Hine)

1. Hind tibiæ with spurs at the tip, sometimes small.................. 2
   Hind tibia without spurs.. 6
2. Third segment of the antenna composed of eight annuli, the first of which is only a little longer than the following ones............ 3
   Third segment of the antenna composed of only five annuli, the first of which is much longer than any of the following ones; ocelli present 5
3. Front of female narrow; ocelli present or absent; fourth posterior cell at least open ....*Pangonia*
   Front of female broad with a large denuded callus; ocelli present.... 4
4. Eyes in the female acutely angulated above; wing in both sexes with a dark picture..*Goniops*
   Eyes in the female not acutely angulated above; wings hyaline in both sexes ....*Apatolestes*
5. Second segment of the antenna about half as long as the first; eyes in life with numerous small dots...........................*Silvius*
   Second segment of the antenna as long or but little shorter than the first; wings with a dark picture...........................*Chrysops*
6. Third segment of the antenna without, or with a rudimentary basal process 7
   Third segment of the antenna with a well developed basal process *Tabanus*[1]
7. Front of female as broad as long, the callus transverse......*Hæmatopota*
   Front of the female narrow.......................................*Diachlorus*

---

[1] Including *Atylotus* and *Therioplectes*.

A description according to Hine of a few of the commoner species is here included.

(1) *Tabanus atratus* Fabricius, the black horsefly (Fig. 111), is from "16–28 mm. in length. The male and female of this common species are easily associated as they differ only in sexual characteristics. The whole insect is uniformly black and the thorax and abdomen in well-preserved specimens are thinly covered with a whitish dust which is easily rubbed off when the specimens are not properly cared for.

"It cannot be confused with any other species recorded, but the smaller specimens resemble *wiedemanni* very closely. The wider front, the longer basal process of the third antennal segment and the shape of the frontal callosity, which is square in *wiedemanni* and wider than high in *atratus*, are distinctive characters. Its much larger size and less shining color distinguish it from *lugubris*."

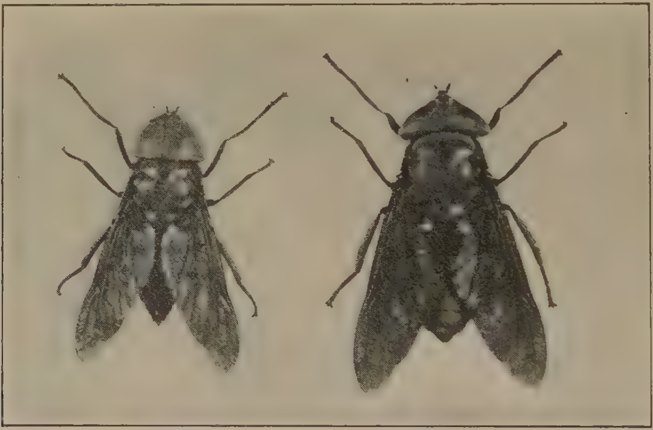

Fig. 111.—The black horsefly (*Tabanus atratus*); male at left, female at right. ×1.5. (Photo by Hine.)

"(2) *Tabanus stygius* Say is the black-and-white horsefly. Length 20–22 mm. Third segment of the antennæ red at base, blackish at apex, first and second segments and palpi dark; legs black, often the tibia reddish at base; wings yellowish brown with posterior border approaching hyaline, a brown spot on the bifurcation of the third vein, also the transverse vein closing the discal cell margined with brownish; abdomen uniform black.

"Female: Thorax dorsally plainly whitish pollinose with more intense longitudinal lines.

"Male: Thorax dorsally uniform grayish brown in well-preserved specimens."

(3) *Tabanus punctifer* O. S. is also a black-and-white horsefly (Fig. 112) resembling *T. stygius,* except that it has the front tibiæ white on the basal third and the thorax uniformly white in both sexes.

(4) *Tabanus costalis* Wied., the green head, is one of the most-dreaded stock pests. "Length 12–14 mm. Palpi yellowish, antennæ brownish with the annulate portion darker; thorax including the scutellum uniformly grayish yellow pollinose; legs largely black, base of front tibiæ and the

middle and hind tibiæ except at apex yellowish; wings hyaline with the costal cells yellowish, veins yellowish; abdomen above alternately striped with black and grayish yellow.

"Female: Frontal callosity black, above with a very much narrowed prolongation, the part of which adjacent to the callosity is sometimes obliterated leaving the upper part as a separate spot.

"Male: This sex is much like the female and easily associated with it, but there is a tendency toward obliteration of the distinct markings of the abdomen, the black of the female is replaced by brownish and the stripes may blend so that the whole base of the abdomen is practically one color."

(5) *Tabanus lineola* Fabr., the lined horsefly (Fig. 113), is also an important stock pest. "Length 12–15 mm. Palpi white; antennæ reddish, annulate portion of third segment darker; thorax brown and gray striped, the latter color not prominent; wings hyaline; legs reddish, apex of the front tibia plainly, apexes of middle and hind tibiæ faintly, and all of the tarsi dark brown; abdomen above brown or black with three prominent, gray stripes.

"The males and females of this species are easily associated. In the latter sex there is sometimes a confusion of colors; the dark is replaced by reddish but the gray middorsal stripe is always prominent in all well-preserved specimens."

(6) *Tabanus sulcifrons* Macq. is known as the autumn horsefly. "Length 18-21 mm. Palpi brownish, antennæ nearly black with the third segment brownish at base; legs dark, bases of tibiæ darker; wings with a distinct brownish tinge, cross veins at the end of the discal cell and bifurcation of the third vein margined with brown.

"Female: front with parallel sides, frontal callosity shining brown, not quite as wide at the front, nearly square and with a linear prolongation above. Segments of the abdomen above with prominent gray, hind margins which expand into large gray triangles in the middle; usually a black mark on the anterior part of each of the second and third segments at the apex of the gray triangle.

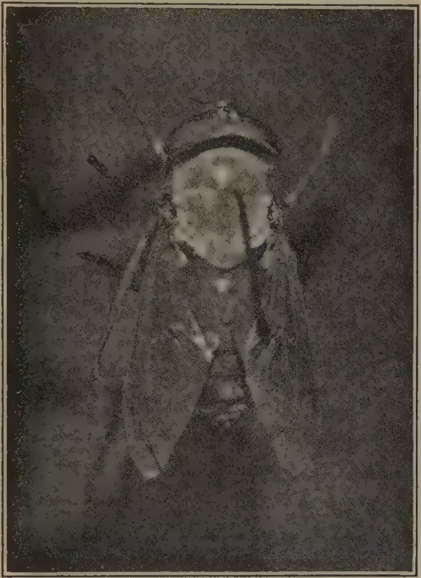

FIG. 112.—A black-and-white horsefly (*Tabanus punctifer*) common in California. × 2.

"Male: The division between the large and small facets of the eye prominent; head slightly more convex than in the female but nearly of the same size, coloration of the whole body the same as in the female."

(7) *Tabanus striatus* Fabr. (Fig. 109) is said to be the most prevalent horsefly of the Philippine Islands, and is known to be an important carrier of Surra. The following description is after Mitzmain (*loc. cit.*)

"The male is very distinct from the female, being smaller and having a larger head and different color markings.

"The distinctly clavate palpi are shorter than in the female, only two-thirds as long as the labium; they are dirty white and fringed with moderately long black hairs.

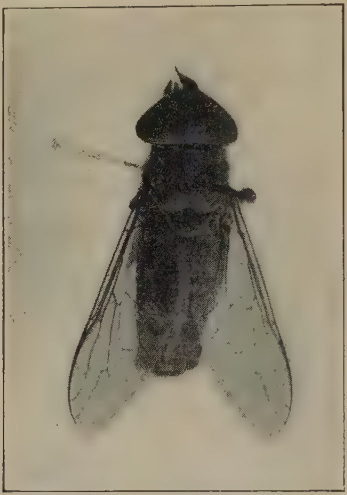

FIG. 113.—The "lined" horsefly (*Tabanus lineola*). × 3.

"The abdominal color markings take the form of a ┬ of pale cadmium yellow in a field of burnt sienna, bordered with pale clay yellow. The area of the large facets of the eyes is colored Roman sepia surrounded by an elliptical band of ultra ash gray. The field of small facets has a mauve fringe bounding an area of iridescent mauve and Prussian green.

"Size: 14 to 15 millimeters.

"Wing expanse: 25 to 28 millimeters.

"Female: The front is narrow, converges slightly anteriorly; the color is golden, marked with a black callosity of irregular form.

"The head is considerably smaller than that of the male; eyes iridescent mauve and Prussian green.

"The palpi are prominently conical, as long as, or slightly longer than, the labium; the color is the same as in the male, mottled with short black hairs.

"The abdomen is alternately striped with Cologne earth and pale clay yellow. The median stripe is pale clay yellow. In both sexes the thorax is indistinctly striped with pale clay yellow and pale brown, and the wings are transparent except the costal and subcostal cells which are pale brown.

"Size: 15 to 17 millimeters.

"Wing expanse: 26.5 to 29 millimeters."

CHAPTER XIII

THE COMMON HOUSE FLY

Order Diptera, Family Muscidæ

LIFE HISTORY, HABITS AND RELATION TO DISEASE

Family Muscidæ.—The family Muscidæ, to which the house fly (*Musca domestica* Linn.) belongs, has the following characteristics:

> "Rather small to moderately large, never elongate, thinly hairy or bare flies. Antennal arista plumose to the tip, sometimes above only, and rarely bare, in which cases the absence of bristles on the abdomen, except at tip, together with the narrowed first posterior cell, characters distinctive of the group, will distinguish the flies belonging here from their allies. Eyes of the male approximated or contiguous; front of female broad. Eyes bare or hairy. Abdomen composed of four visible segments. Genitalia not prominent" (Williston[1]).

Characterization of the House Fly.—Hewitt's[2] description of the house fly after Schinir is undoubtedly the best for our purpose, viz.:

> "Frons of male occupying a fourth part of the breadth of the head. Frontal stripe of female narrow in front, so broad behind that it entirely fills up the width of the frons. The dorsal region of the thorax dusty gray in color with four equally broad longitudinal stripes. Scutellum gray with black sides. The light regions of the abdomen yellowish, transparent, the darkest parts at least at the base of the ventral side yellow. The last segment and a dorsal line blackish brown. Seen from behind and against the light the whole abdomen shimmering yellow, and only on each side of the dorsal line on each segment a dull transverse band. The lower part of the face silky yellow, shot with blackish brown. Median stripe velvety black. Antennæ brown. Palpi black. Legs blackish brown. Wings tinged with pale gray with yellowish base. The female has a broad velvety black, often reddishly shimmering, frontal stripe, which is not broader at the anterior end than the bases of the antennæ, but becomes so very much broader above that the light dustiness of the sides is entirely obliterated, the abdomen gradually becoming darker. The shimmering areas of the separate segments generally brownish. All the other parts are the same as in the male. Mature insect 6–7 mm. in length, 13–15 mm. across the wings" (Fig. 114).

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[1] Williston, S. W., 1896. Manual of North American Diptera. James T. Hathaway, New Haven.

[2] Hewitt, C. Gordon, 1910. The House Fly, xiii + 195 pp. The University Press, Manchester, England.

Why called House Fly.—Out of a total of 23,087 flies collected by Howard[1] in dining rooms in different parts of the country 22,808 or 98 per cent of the whole number were *Musca domestica*. Again out of a total of 294 flies collected by the writer, representing the entire fly population of one house, 202 or 94.4 per cent were *Musca domestica*. Thus the term *common house fly* is not misapplied. Several of the commoner species of flies found indoors are shown in the accompanying illustration (Fig. 115).

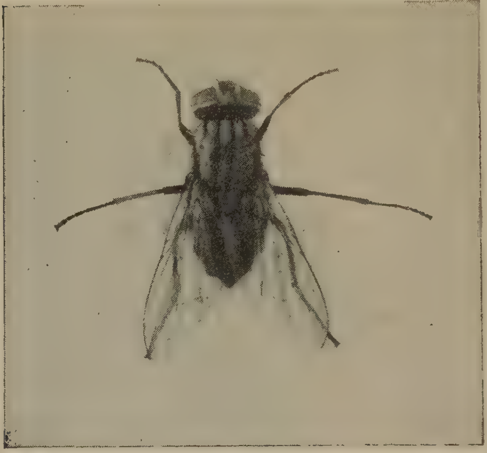

FIG. 114.—The common house fly (*Musca domestica* Linn). × 4.

Distribution of Sexes.—In order to determine the distribution of the sexes, observations were made under two different conditions, viz., first, six sweepings with an insect net were made over a horse-manure pile on which many flies had gathered (the results are shown in Table VIII); second, all but half a dozen flies were collected in one house, giving a fairly representative lot for indoors, even under screened conditions (Table IX).

TABLE VIII

SHOWING RESULTS WITH REGARD TO SEX AND SPECIES IN SIX SWEEPINGS FROM A HORSE MANURE PILE ON MAY 19, 1909

	FIRST		SECOND		THIRD		FOURTH		FIFTH		SIXTH		TOTAL	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
House fly (*Musca domestica*)	7	153	4	81	3	64	9	77	4	210	5	112	32	697
Muscina sp.	2	6	0	7	0	5	2	5	3	10	1	4	8	37
Blowfly (*Calliphora* sp.)	2	2	0	1	1	0	0	0	0	0	1	0	3	3
Lucilia cæsar	0	1	0	1	0	1	0	1	0	0	0	0	0	4
Other species.........	1	4	0	4	2	1	4	2	4	2	2	0	13	13
Totals	12	166	4	94	6	71	15	85	11	222	9	116	56	754

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[1] Howard, L. O., 1900. A Contribution to the Study of the Insect Fauna of Human Excrement. Proc. Wash. Acad. of Sciences, Vol. II, Dec. 28, pp. 541-604.

TABLE IX

SHOWING NUMBER OF INDIVIDUALS COLLECTED IN A SCREENED DWELLING JUNE 1, 1909, REPRESENTING THE ENTIRE FLY POPULATION OF THE SAME

	♂	♀
House fly (*Musca domestica*)	86	116
Muscina sp.	3	1
Homalomyia sp.	5	0
Calliphora sp.	1	2
Totals	95	119

Explanation and Comparison of Tables VIII and IX.—These two tables give us some information as to the relative abundance of the house fly, and the distribution of the sexes. Table VIII shows clearly that of those flies which frequent both the manure pile and the home, the house fly (*Musca domestica*) composes 90 per cent, and that of the total collected, over 95 per cent (95.4 per cent) were females. Thus, it is clear that it is the "instinct" to oviposit (to lay eggs) that has mainly attracted these insects to the manure. In fact, fresher parts of the manure pile are often literally white with house-fly eggs in countless numbers. Observations made in the near vicinity of the manure pile proved that certainly the same percentage (over 95 per cent) of the flies clinging to the walls of the stable, boxes and so on were males.

That the number of males and females in the house fly is normally about equal is evidenced by the fact that of a total of 264 pupæ collected indiscriminately and allowed to emerge in the laboratory, 129 were males and 135 were females. The author has, however, made observations on certain flesh flies, *Lucilia cæsar* Linn. and *Calliphora vomitoria* Linn., which indicate that the factor of underfeeding must be considered in this connection. From a large amount of unpublished data, it is evident that underfeeding results in the emergence of a greater percentage of males. This does not imply, however, that sex is influenced by feeding; it only indicates that cutting short on food supply destroys the larval females first. Feeding experiments on the house fly indicate that the same holds true here, but also that this insect is not so plastic as the flesh fly, hence does not vary so greatly in size and dies more easily when underfed.

Of the total number of house flies (202) collected indoors (June, 1909), representing all but perhaps six of the total number in that particular house, 57 per cent were females, showing nearly equal distribution for the sexes. This would, it seems, indicate that males and females are equally attracted to the house by odors issuing therefrom.

Life History.—The house fly passes through a complex metamorphosis (Fig. 116), i.e., egg, larva (maggot), pupa (resting stage) and imago or full-grown winged insect.

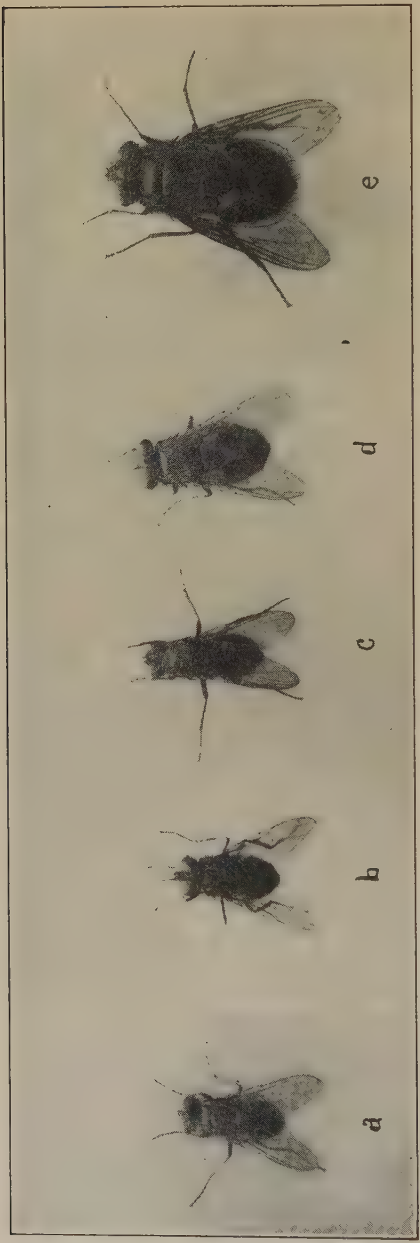

FIG. 115.—Flies commonly seen indoors: (*a*) the house fly (*Musca domestica*), (*b*) the stable fly (*Stomoxys calcitrans*), (*c*) an anthomyid fly, (*d*) the greenbottle fly (*Lucilia cæsar*), (*e*) the bluebottle fly (*Calliphora vomitoria*). × 2.

From 75 to 150 eggs are deposited singly, piling up in masses, and there are usually several such layings at intervals of three or four days. Female flies begin depositing eggs from 9 to 12 days after emerging from the pupa case. Dunn,[1] Entomologist, Board of Health Laboratory, Ancon, Canal Zone, reporting on his observations states that as many as 159 eggs may be deposited in one batch, that large batches are sometimes deposited at intervals of but 36 hours, and that one female may deposit as many as 21 batches, or a total of 2,387 eggs in 31 days after emergence. He also states that oviposition may take place as early as 2¼ days after emergence, and that copulation may occur within 24 hours after emergence and one successful copulation seems to be sufficient to fertilize the female for her life period. Excrementous material, especially of the horse (Figs. 117 and 118), is the favorite material upon which the eggs are deposited and upon which the larvæ feed. Other suitable situations are kitchen refuse brewer's grain and other decaying vegetable matter. Where the city garbage is carefully disposed of with only ordinary attention to horse manure, it seems quite safe to say that 95 per cent of the house flies are bred in the latter. The house fly does not breed so abundantly in cow manure, although plentifully enough to take such material into consideration, especially when it occurs in piles mixed with bedding. The eggs of the house fly hatch in from 12 to 24 hours; the newly hatched larvæ begin feeding at once and grow rapidly.

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[1] Dunn, L. H., 1923. Observations on the oviposition of the house fly, *Musca domestica,* in Panama. Bull. Ento. Res., Vol. XIII, Part 3, pp. 301-305.

To gain an estimate of the number of larvæ developing in an average horse-manure pile, samples were taken after four days' exposure to flies, with the following results: first sample (4 lbs.) contained 6,873 larvæ; second sample (4 lbs.), 1,142; third sample (4 lbs.), 1,585; fourth sample (3 lbs.), 682; total 10,282 larvæ in 15 pounds. All of the larvæ were quite or nearly full grown. This gives an average of 685 larvæ per pound. The weight of the entire pile was estimated at not less than 1,000 pounds, of which certainly two thirds was infested. A little arithmetic gives us the astonishing estimate of 455,525 larvæ (685 × 665), or in round numbers 450,000, i.e., about 900,000 larvæ per ton of manure after only four days' standing. This particular manure pile (not from a livery stable, either) was only one of many known to exist in various parts of the city. No wonder flies fairly swarm in the vicinity of these choice ornaments!

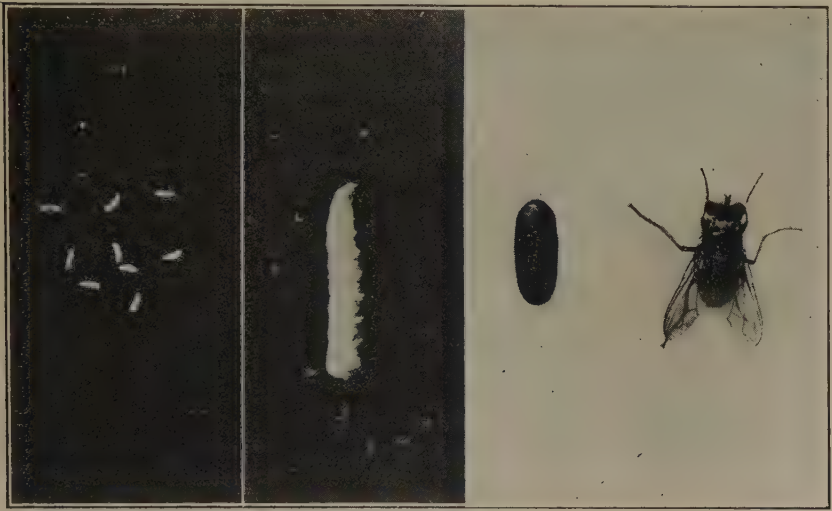

FIG. 116.—Life history of common house fly. (*a*) eggs; (*b*) larva; (*c*) pupa; (*d*) imago or adult. × 2.

The larval stage is the growing period of the fly, and the size of the adult will depend entirely upon the size that the larva attains. An underfed larva will result in an undersized adult. The growing stage requires from 4 to 6 days, after which the maggots often crawl away from their breeding place, many of them burrowing into the loose ground just beneath the manure pile, or under boards or stones, or into dry manure collected under platforms and the like. (One and three fourths pounds of dry manure, taken from beneath a platform, contained 2,561 pupæ.) The larvæ often pass 3 or 4 days in the prepupal or migrating stage before actually pupating; but in a given set of individuals under similar conditions the various stages are remarkably similar in duration,—when one pupates, the rest will certainly follow in short order, and when one emerges, others quickly appear. The average time required for development from the egg to the imago is differently estimated by various observers, inasmuch as temperature greatly influences the time required. Packard (1874) gives the time at from 10 to 14 days, Howard (1906), at Washington, D. C., as 10 days. In Berkeley, California, where the weather is uniformly cool (rarely above 80° F. and a mean of 48° F. during the winter months), the life cycle is completed usually in from 14 to 18 days, less often in 12 days. At a maintained temperature of 30° C. the minimum time required for complete metamorphosis is 9⅓ days. Prolonged cool weather or artificially cooled environment results in greater retardation. Even allowing for such retardation, the number of generations produced during the summer is quite large, and in California (Berkeley) I have seen house flies emerging from their breeding places during every month of the winter season. This latter fact lends even greater importance to a house-fly campaign. In early March a veritable pest of flies was

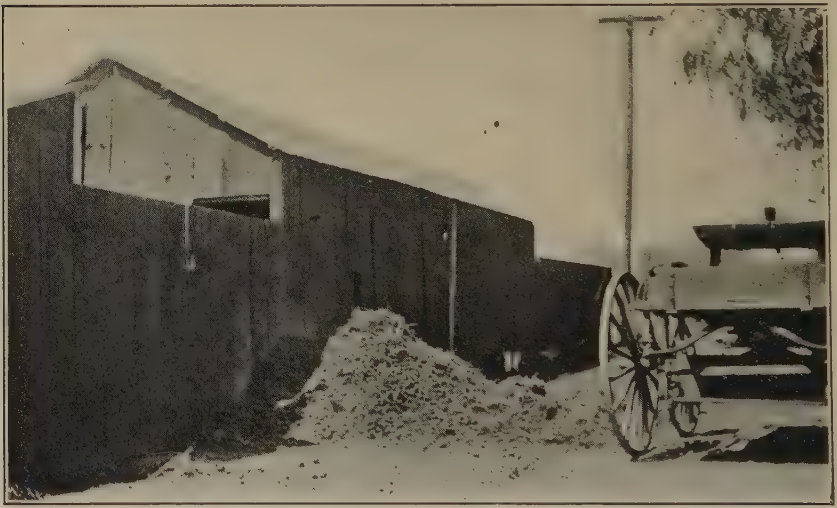

FIG. 117.—A typical rural fly breeding place,—the everlasting manure pile. The principal menace is the fresh, warm manure added on top daily.

encountered while on a trip through the Imperial Valley (California).

When the fly emerges from the pupa case with fully developed wings, it is as large as it will ever be, except in expansion and addition in weight, due to stomach contents or development of eggs in the female. This explains why no young house flies are seen (young in the sense of being small). The little flies upon the windows are not "baby" flies, but belong to another species, also adult. One can easily influence the size of a fly by underfeeding it in the larval stage, as illustrated in Fig. 119 (see Herms,[1] 1907). The question has been asked, "Why are all house flies so nearly of one size?" This is not altogether true. There are some undersized house flies, but the great majority of the larvæ or maggots find ample food for optimum development. Furthermore, experiments show that the house fly is not as plastic in respect to food conditions as the flesh fly; in other words, larvæ which are underfed perish easily.

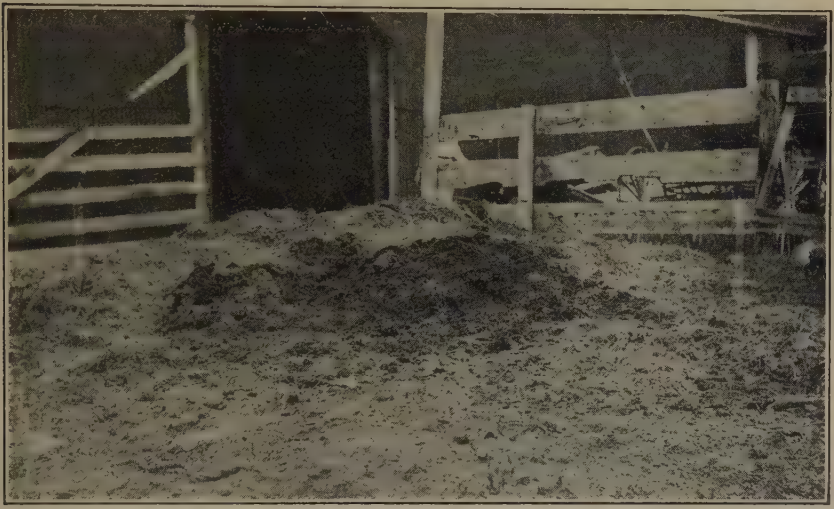

Fig. 118.—Fly maggots will be found in abundance in similar manure piles. This is surely not sufficiently ornamental to maintain indefinitely, nor will it improve the health of the neighbors.

House flies reach sexual maturity in two to four days and begin to deposit eggs on the third to ninth day after emergence from the pupa. Sunshine stimulates their breeding habits.

Estimating that one adult fly deposits from 120 to 150 eggs with at least six lots at intervals of from 3 to 4 days, Hodge[2] gives us the following astounding statement: "A pair of flies beginning operations in April may be progenitors, if all were to live, of 191,010,000,000,000,000 flies by August. Allowing one eighth of a cubic inch to a fly, this number would cover the earth 47 feet deep."

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[1] Herms, W. B., 1907. An Ecological and Experimental Study of Sarcophagidæ. Journ. Exp. Zool., Vol. IV, No. 1, pp. 45-83.

[2] Hodge, C. F., 1911. Nature and Culture, July, 1911.

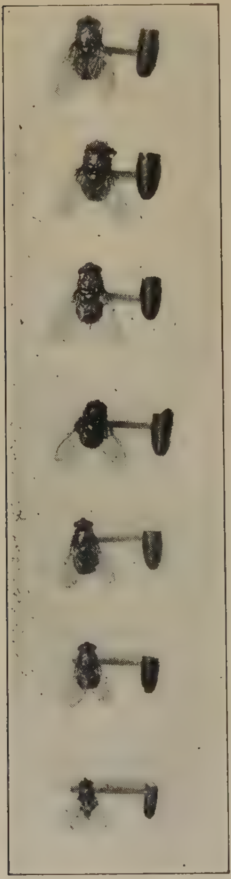

FIG. 119.—Illustrating the effect that underfeeding the larva has on the size of the adult fly (*Lucilia cæsar*). Overfeeding, if it does not result fatally, does not increase the size of the fly over the optimum, as may be seen by the uppermost individual, which is the same size as the next lower individual or optimum. Each of the next lower individuals is the result of decreasing the time of feeding by six hours. These results are based on a large number of individuals in each case. × 1.

Influence of Temperature on Life History.—While conducting an extensive series of experiments in which many hundreds of house flies were used in all stages, a record was made of the temperature at which the containers were kept. Ordinarily not more than one to three quarts of manure were used for the growing maggots, hence the temperature of the environment did not differ widely from that of the manure. The temperature of an average manure pile to which material is added daily varies from 18° C. to 66° C. Young growing larvæ are most numerous at temperatures varying from 45° to 55°. Below 45° half-grown and full-grown larvæ occur and above 55° the temperature seems to become too great.

From the following table (Table X) it will be seen that temperature influences the time required for the development from egg to imago very materially, but nevertheless with an average outdoor temperature of 18° C. flies ordinarily require only from 12 to 14 days to pass through the same stages; this is of course due to the higher temperature of the manure pile, as already indicated above. The shortest time required for complete metamorphosis is seen to be 9⅓ days.

Other Breeding Places.—Stable yards and empty town lots used for horses are often a source of many flies. Here the droppings from the horses accumulate and are kept moist by urine, thus affording good breeding places (Fig. 120). *The stable yard and town lot used for horses must not be overlooked in the campaign against the house fly.* Merely sweeping up the manure with a broom after the removal of the manure pile or superficial shoveling without scraping up the loose earth will not remedy the matter entirely. It must be borne in mind that when the larvæ have fed sufficiently for full growth, that is, from four to five days, they crawl into the loose earth

TABLE X

SHOWING INFLUENCE OF TEMPERATURE ON THE LENGTH OF LIFE HISTORY OF MUSCA DOMESTICA

The insects were kept at the temperature indicated from egg to emergence of the imago. The average temperature is here given, the variation from the average was probably not more than ± 1°. Temperature of the air and not of the manure is here considered.

	16° C		18° C		20° C		25° C		30° C	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Egg stage ...	36 hrs.	40 hrs.	27 hrs.	30 hrs.	20 hrs.	30 hrs.	12 hrs.	20 hrs.	8 hrs.	12 hrs.
Larval stage ..	11 ds.	26 ds.	10 ds.	14 ds.	8 ds.	10 ds.	7 ds.	8 ds.	5 ds.	6 ds.
Pupa stage ..	18 ds.	21 ds.	12 ds.	15 ds.	10 ds.	11 ds.	7 ds.	9 ds.	4 ds.	5 ds.
Total time required from egg to imago	40½ ds.	48⅔ ds.	23⅛ ds.	30¼ ds	18⅚ ds.	22¼ ds.	14½ ds.	17⅚ ds.	9⅓ds.	11½ ds.
Average time required to develop from egg to imago	44.8 days		26.7 days.		20.5 days		16.1 days		10.4 days	

underneath the manure pile (often great pockets of larvæ may be found thus), or they wander to loose débris in the immediate vicinity; many, of course, remain in the drier portions of the manure pile to complete their life cycle. Thousands of pupæ (recognized as chestnut-colored, barrel-shaped objects) were taken by the writer in one instance from beneath a platform leading into a stable. Therefore, when cleaning up, such conditions and situations must also be taken into account.

While horse manure is certainly a favorite larval food and is commonly regarded as the chief factor in the breeding of house flies, and it certainly is under most rural and small town conditions, other factors may arise which are vastly more important, particularly in this day of the automobile and tractor. Cow manure if well mixed with bedding is frequently an important factor in the development of flies. Flies will also breed freely in hog manure, but the swarms of flies about the pig pens usually originate in the waste feed, slops, etc., as later discussed. Chicken manure is the most important factor in the breeding of flies in our poultry districts and the pest of blowflies in such districts is the result of dead birds buried in shallow pits or simply disposed of by throwing them into a gulley or in a corner. The dead birds (large or small) should be burned or buried with crude oil, plenty of lime or sprayed with creosote oil. Human excrement is a very dangerous substance and if exposed to flies in open privies becomes a very prolific breeding place, which emphasizes the need of flyproof privies or other means to prevent flies from gaining access or to repel them.

Great swarms of flies are often found around feed troughs and the animals (hogs and cattle) may be literally covered with them. An examination of the waste feed behind or beneath the troughs or in and about the mixing vats will almost invariably reveal numerous maggots. Storage receptacles for slops sometimes present a wriggling mass of maggots. The correction of such fly-breeding manifestly depends upon greater cleanliness and care in handling the mash, wet or dry. The addition of a very small quantity of turpentine to vessels containing kitchen slops acts as a repellent and is harmless. Spraying fences, walls and floors with creosote oil gives beneficial results also and is not as disagreeable as crude oil or fuel oil, all of which, of course, add somewhat to the fire risk.

It frequently happens that brewer's grain or spent hops, bran mash and ensilage are only partly consumed by the animals and the waste is thrown out into the fields in heaps. Such heaps of waste are commonly a source of enormous numbers of flies about dairies where otherwise conditions may be very good and no apparent reason for the swarms of flies exists. In dealing with such wastes the general principle of scattering the waste in a thin layer so as to hasten drying and thus prevent fly-breeding must be observed.

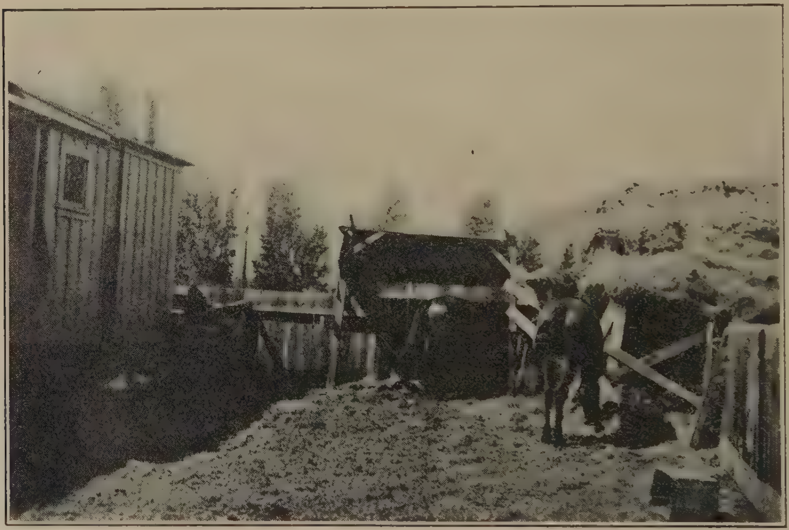

Fig. 120.—A manure-covered corral kept moist by urine from the horses forms an important breeding place for both house flies and stable flies.

Garbage heaps, particularly when fermentation and decomposition begin, are commonly sources of many flies of many kinds. Heaps of decaying onions and other vegetables, fruits, etc., as well as decaying straw and weeds, may become infested with maggots. Spraying such heaps with crude oil or fuel oil gives good results and unless there is danger or some other good reason, a match should be applied. Smoking and smoldering garbage heaps seldom breed flies except where garbage is carelessly added. Every household in every community should be provided with a garbage can equipped with a tight-fitting lid, and all liquid matter should be drained from the kitchen refuse at the sink and only solids placed in the garbage can, and these should first be wrapped in a newspaper. This may seem "finicky," but it is time well spent and it is worth trying, both from the standpoint of fly control and from the standpoint of your nostrils as well. Do not bury garbage except as already explained, and never allow garbage to accumulate in heaps in backyard or alley (Fig. 121).

In the absence of sewers or septic tanks in the country the dishwater from the kitchen is frequently piped from the sink to a ditch in the back yard. On many occasions these ditches become clogged and vile smelling and an examination will reveal numerous maggots developing in the muck—a source of flies commonly overlooked.

Fig. 121.—A poor excuse for a fly-tight garbage can. This should be regulated by ordinance.

The writer has also seen so-called uncovered septic tanks literally reeking with maggots and he has also seen covered septic tanks (with crevices, however, between the boards) which have been responsible for hordes of flies. Maggots were found in countless numbers in the soft sludge mat covering the liquid in the tank.

Range of Flight.—Ordinarily under city conditions it may be safely said that where flies are abundant they have been bred in the same city block or one immediately adjacent. The house fly can, however, use its wings effectively and may be carried by the wind, though it usually seeks protection very quickly when a strong breeze blows. Where houses are situated close together flies have the opportunity to travel considerable distances by easy flights and they are often carried on meat and milk delivery wagons, animals, etc.

In a most illuminating experiment by Copeman[1] *et al.*, it has been shown that house flies may invade a community at a distance of from 300 yards to 17,000 yards from their breeding place; in this case a refuse heap.

In a certain city in Montana 387,877 marked flies were liberated from a release point and a total of 1,056 flies were recaptured at seventy-eight stations which varied from 50 to 3,500 yards from the point of release.[2]

Longevity of Flies.—In order to determine the longevity of flies it is necessary to keep the same individual under observation from the time of emergence from the pupa to the time of death. The writer has done this by keeping each pupa in a separate vial, noting the time of emergence to the hour and spotting each fly lightly with Chinese white dorsally on the thorax. The spots can be arranged singly and in combination so that many different flies can be kept under observation at the same time. After marking, the flies were liberated in bobbinet-covered cages (size of cages never more than 8″ × 10″ × 18″). Each cage was provided with sugar water and a receptacle of horse manure. A full set of experiments under sufficiently varying conditions indicate an average life of close to 30 days with a maximum life of something over 60 days during the summer months. In hibernation flies may live over winter, i.e., from October to April, which is the case in our Eastern and Central states. In California, flies emerge from their pupa cases throughout the winter, and their life history is then considerably longer than in summer.

Relation to Light.—In determining methods of control, the normal behavior of organisms under natural stimuli should be taken into account and applied wherever possible. The better acquainted we are with the normal behavior of any organism, including the life history, the better able are we to cope with it.

The larvæ of the house fly when normal respond negatively to light upward of .00098 C. M., i.e., crawl away from the source of light and into darker areas. This reaction is useful to the larvæ because light and its heating or desiccating effect is injurious both directly and indirectly,—the latter because sunlight dries out the food material unless heaped up, and dry matter is unfavorable for the growth of the larvæ.

On the other hand, the adult flies respond positively to light, going toward the source of light. This reaction is less pronounced in the females, as may be seen from the following table (Table XI).

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[1] Copeman, Howlett and Merriman, 1911. In reports to the local Government Board of Public Health and Medical Subjects. New Series No. 53, Report No. 4 on Flies as Carriers of Infection (London).

[2] Parker, R. R., 1916. Dispersion of Musca domestica Linn. under city conditions in Montana. Journ. Econ. Ento., Vol. 9, No. 3, pp. 325-354.

TABLE XI

SHOWING THE RESPONSE OF ADULT HOUSE FLIES TO LIGHT, UNDER VARIOUS INTENSITIES

The source of light in all cases was an incandescent lamp; the several intensities were secured by means of diaphragms in a low-intensity dark box such as has been described by the author (*loc. cit.* 1911).

INTENSITY	SEX	NO. OF TRIALS	AVERAGE TIME REQUIRED FOR RESPONSE	PER CENT OF RESPONSES UNDER THREE SECONDS	CHARACTER OF RESPONSE			PERCENTAGE OF POSITIVE REACTIONS
					Toward	Away	Indiff.	
256 C. M.	both	25	55.4 sec.	32%	19	6	0	76%
.2533 C. M.	male	50	8.86 sec.	62%	58	2	0	97%
.2533 C. M.	female	50	25.44 sec.	50%	44	2	4	88%
.0633 C. M.	both	50	24.68 sec.	26%	41	3	6	82%

From the above table it must be concluded that the house fly responds positively to light (goes toward the source of light), even in very low intensities, at least as low as .0055 C. M. and that the male is far more responsive to this stimulus than is the female.

The female is less reactive to light and more reactive to chemical stimuli such as odors, which enable her to find the proper place for the deposition of eggs and food for the larvæ. Because of the more or less pronounced relation to light, manures deposited in dark places are less likely to breed flies. Flies can commonly be observed coming to rest in sunny spots in preference to shade, shunning the shadows.

Large areas of light are always preferred to small areas of light even though the intensity is the same. The following experiment furnishes evidence. Two areas of light with a ratio of 1:3000 and a light intensity of 7.25 candle meters were placed opposite each other at a distance of one meter, the experimental room being otherwise completely darkened and painted dead black. Fifty flies were tested, giving each fly five trials midway between the light areas. Out of 250 trials 149 were toward the larger area, 93 toward the lesser and 8 were indifferent, i.e., 59.6 per cent toward the larger. This experiment shows that the flies respond positively to light and select the larger area by preference. Whether this indicates a degree of image-forming powers or not need not be considered here, but the writer[1] has found that certain flesh flies also respond more readily to the larger area, that is a response of

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[1] Herms, W. B., 1911. The Photic Reactions of Sarcophagid Flies, especially *Lucilia cæsar* Linn. and *Calliphora vomitoria* Linn. Journ. Exp. Zoöl., Vol. X, No. 2, pp. 167-226.

74 per cent, and Cole[1] found that the mourning cloak butterfly shows a response of 87.2 per cent.

The response to light can be made use of in a practical way, first by placing the stable manures in which the flies breed in darker portions of the stable so that the light reactions of the flies will take them away from the manure and toward the source of light; secondly, manure

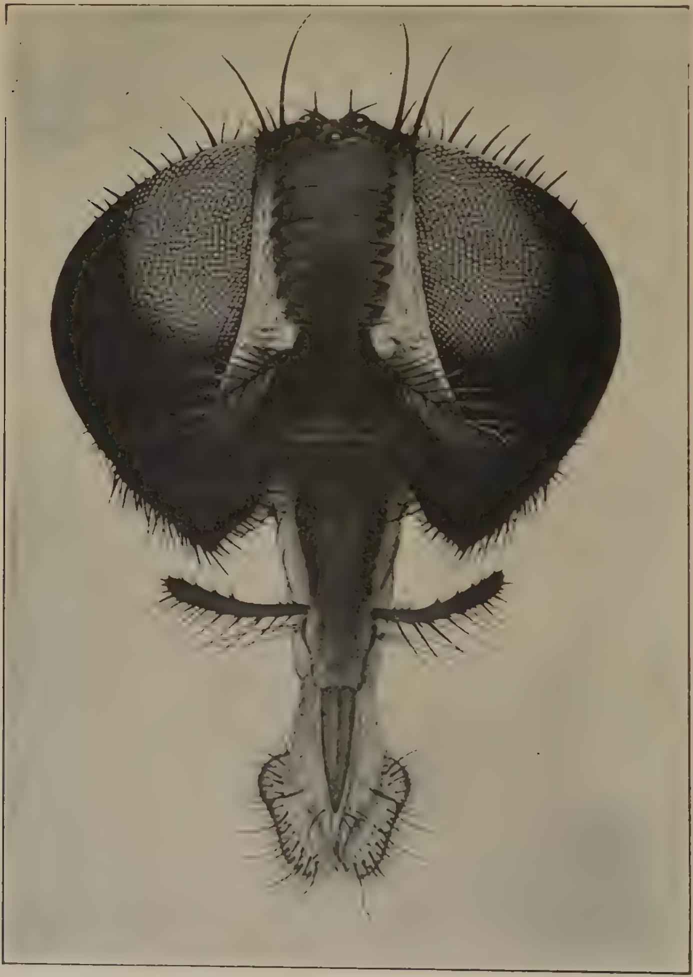

FIG. 122.—Head of the common house fly, front view. (Much enlarged.)

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[1] Cole, Leon J., 1907. An experimental study of the image-forming powers of various types of eyes. Proc. Amer. Acad. Arts & Sci., Vol. 42, No. 16, pp 335-417.

boxes should be so constructed that flies finding their way into the box or developing therein are afforded an opportunity to fly toward a light opening which leads into a fly trap.

Germ Carrier.—The house fly is by accident of habit and structure one of the most important and dangerous of disease-transmitting insects. In habit the house fly is revoltingly filthy, feeding indiscriminately on excrement of all kinds, on vomit and sputum, and is, on the other hand, equally attracted to the daintiest food of man, and will, if unhindered, pass back and forth between the two extremes. The house fly's proboscis (Fig. 122) is provided with a profusion of fine hairs which serve as collectors of germs and filth; the foot (Fig. 123) of the fly when examined under the microscope presents an astonishing complexity of structure. Each of the six feet is equally fitted with bristly structures and pads, which latter secrete a sticky material, adding thus to the collecting powers. This structural condition, added to the natural vile habit of the house fly, completes its requirements as a transmitter of infectious diseases of certain types.

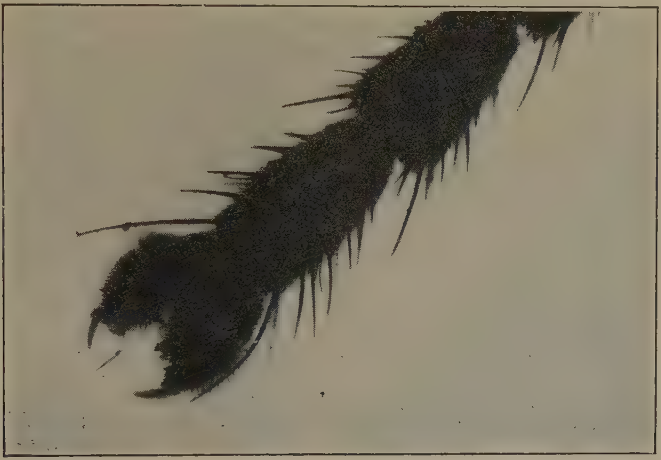

FIG. 123.—Foot of the common house fly. (Much enlarged.)

This creature has long been known to contaminate food, but has, nevertheless, been regarded as a scavenger, and thus as a real servant of man; but if there remains any doubt in the mind of the reader, after reading what follows, as to the necessity of getting ride of this wolf in sheep's clothing, let him take the time to make a few careful observations for himself.

Circumstantial evidence against the house fly as a transmitter of such infectious diseases as typhoid fever, tuberculosis, dysentery and cholera, is complete as summed up thus: First, it possesses the best possible structures for the conveyance of "germs" and filth; second, it possesses the habit of feeding on excrement, vomit and sputum; third, the causative organisms ("germs") of the above-named diseases may be present in the matter mentioned in the second clause; fourth, the house fly is the principal fly found in dwellings, alighting on the prepared food of man, or on food products in grocery stores, fruit stands and meat markets.

Experimental evidence that the house fly actually does carry bacteria on its mouthparts and feet and in its intestinal tract is not wanting. To illustrate, the following simple experiment may be cited.

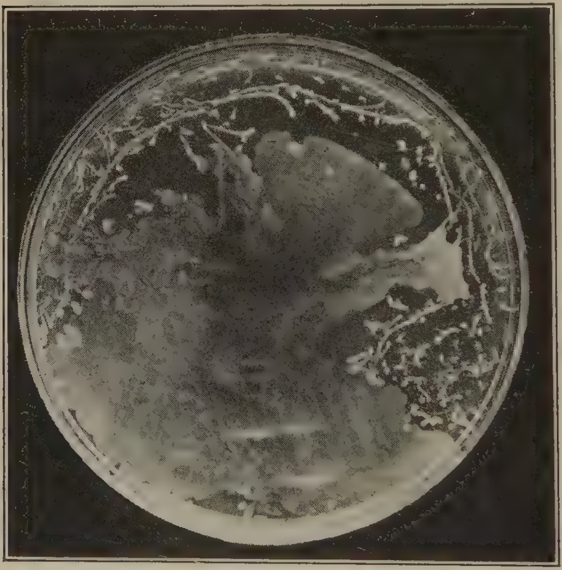

Fig. 124.—Cultures of *Staphylococcus aureus* transferred by a house fly to a sterile agar plate upon which it was allowed to crawl for three minutes. Incubation period, 24 hours.

In order to show that the house fly (*Musca domestica*) can carry "germs" of a known kind, a partially sterilized fly was placed in a test tube containing a culture of *Staphylococcus aureus.* After walking about in this tube and becoming contaminated with the *Staphylococci,* the fly was transferred to a sterile agar-agar plate upon which it was allowed to crawl about for three minutes. The plate was then incubated for twenty-four hours, after which it was examined and photographed (Fig. 124).

The photograph shows the trail of the fly as it had walked about. Every place that the foot touched is plainly marked by a vigorous bacterial growth. That the fly cannot easily get rid of all the bacteria on its feet is also illustrated by this photograph, inasmuch as three minutes spent crawling about on the agar plate did not apparently lessen the growth-vigor of bacteria deposited, and a second plate of agar-agar contaminated by the same fly immediately after exposure of the first plate gave equally astonishing results. The same experiment was performed, using *Bacillus prodigeosus* with even more pronounced results. These experiments were repeated several times with like effect.

A second series of experiments was carried on as follows: During the middle of May (1909) house flies were captured in various parts of Berkeley, placed at once in sterilized vials, and in the laboratory placed under bell jars with agar-agar plates, all under sterilized conditions. After the flies had crawled about on the culture media, the latter were incubated for twenty-four hours. In every case but one a strong growth of bacteria appeared. This one was incubated longer and after forty hours four centers of infection appeared. This fly had been taken on a sunny wall on one of the main streets, and having been under observation in this position for a long time (as reported by the assistant) it was first supposed that the action of the sunlight had sterilized it. This series of experiments included flies taken from a number of situations, namely, principal thoroughfares, sunny walls, street corners, manure piles and the dining room. Without exception the flies were laden with bacteria, and in all cases the greatest care was exercised not to introduce accidental infection to the culture plates.

Probably the most accurate study of these factors was carried on by Esten and Mason[1] on the *Sources of Bacteria in Milk* and certainly most striking facts were revealed. The following table (Table XII) and attached remarks are taken from that publication, and need no further comment or explanation.

> "From the following table the bacterial population of 414 flies is pretty well represented. The domestic fly is passing from a disgusting nuisance and troublesome pest to a reputation of being a dangerous enemy to human health. . . . The numbers of bacteria on a single fly may range all the way from 550 to 6,600,000. Early in the fly season the numbers of bacteria on flies are comparatively very small, while later the numbers are comparatively very large. The place where flies live also determines largely the number that they carry. *The average for 414 flies was about one and one-fourth million bacteria on each.* It hardly seems possible for so small a bit of life to carry so large a number of organisms. . . . The objectionable class coliaerogenes type was two and one-half times as abundant as the favorable acid type."

From the experiments previously cited it may be seen that the fly becomes infected by walking over infective materials, both its feet and wings becoming contaminated. The intestinal contents of flies become infected by feeding on infective material, and bacteria are dejected in the fly "specks." It furthermore seems plausible that flies might become infected in the larval stage by developing in fecal matter and that the newly emerged flies would already be dangerous. Under experimental conditions Graham-Smith[2] has produced infected blowflies by

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[1] Esten and Mason, 1908. Sources of Bacteria in Milk. Storrs Agric. Exp. Sta., Bull. No. 51.

[2] Graham-Smith, G. S., 1911. Further observations on the ways in which artificially infected flies carry and distribute pathogenic and other bacteria. Reports of the local Government Board on Public Health and Medical Subjects. (New Series No. 53.) Further Reports No. 4, pp. 31-48.

TABLE XII

Source of Bacteria from Flies

1907	Source	Total Number	Total Acid Bacteria	Rapid Liquefying Bacteria	Slow Liquefying Bacteria	Bacterium lactis acidi, Group A, Class 1	Coli-aerogenes, Group A, Class 2
July 27	[a] 1 fly. Bacteriological laboratory..	3,150	250	600	100	......	......
July 27	[b] 1 fly. Bacteriological laboratory..	550	100	......	......	......	......
August 6	[c] 19 cow stable flies..............	7,980,000	220,000	......	20,000	......	......
	Average per fly..................	420,000	11,600	......	1,000	......	......
August 14	[d] 94 swill barrel flies.............	155,000,000	8,950,000	......	......	4,320,000	4,630,000
	Average per fly..................	1,660,000	95,300	......	......	46,000	49,300
August 14	[e] 144 pigpen flies.................	133,000,000	2,110,000	100,000	266,000	933,000	1,176,000
	Average per fly..................	923,000	18,700	700	1,150	6,500	12,200
September 4	[f] 18 swill barrel flies.............	118,800,000	40,480,000	......	14,500,000	10,480,000	30,000,000
	Average per fly..................	6,600,000	2,182,000	......	804,000	582,000	1,600,000
September 21	[g] 30 dwelling house flies..........	1,425,000	125,000	......	12,500	......	......
	Average per fly..................	47,580	4,167	......	417	......	......
September 21	[h] 26 dwelling house flies..........	22,880,000	22,596,000	120,000	34,000	......	......
	Average per fly..................	880,000	869,000	4,600	1,300	......	......
September 27	[i] 110 dwelling house flies.........	35,500,000	13,670,000	8,840,000	125,000	......	......
	Average per fly..................	322,700	124,200	80,300	1,100	......	......
August 20	[j] 1 large bluebottle blowfly.......	308,700	2,200	mould spores	......	......	......
	Total average of 414 flies...........	1,222,570	367,300	7,830	73,500	......	......
	Average per cent of 414 flies.........	......	30%	.6%	6%	......	......
	Average per fly of 256 flies, experiments [d], [e], [f]...........	3,061,000	765,000	230	268,700	211,500	553,800
	Average per cent of 256 flies, experiments [d], [e], [f]...........	......	25%	......	8%	7%	18%

feeding the larvæ on meat infected with spores of *Bacillus anthracis*. He found that the blowflies remained heavily infected for at least two days after emerging and that the bacillus could be cultivated either from the limbs or intestinal contents of the flies more than fifteen or nineteen days old.

Human foods are infected by flies primarily by direct contact through the touch of feet, proboscides and wings; and secondly, through fly "specks" (feces); and finally, flies grossly infect liquids by accidentally dropping into the fluid,—this is especially true of milk.

The opportunity for flies to become infected is so great in all communities, even the most sanitary, that no fly should be trusted to alight on food prepared for human consumption. The following quotation from Nuttall,[1] whose careful judgment is here considered, is directly

> "It should be remembered that a fly may cause relatively gross infection of any food upon which it alights after having fed upon infective substances, be they typhoid, cholera or diarrhea stools. Not only is its

to the point, viz.:—

> exterior contaminated, but its intestine is charged with infective material in concentrated form which may be discharged undigested upon fresh food which it seeks. Consequently, the excrement voided by a single fly may contain a greater quantity of the infective agents than, for instance, a sample of infected water. In potential possibilities the droppings of one fly may, in certain circumstances, weigh in the balance as against buckets of water or of milk!"

Relation to Disease.—Apparently as early as about the fourteenth century B.C. flies were looked upon as of sanitary importance, if the following quotation from Mosaic writings is correctly interpreted, viz.: "and there came a grievous swarm of flies into the house of Pharaoh, and into his servants' houses, and into all the land of Egypt and the land was corrupted by reason of the swarm of flies." It is quite likely that some of the plagues striking both human beings and cattle originated as the result of the swarms of flies. As early as 1577 the manner in which flies relate to disease, i.e., by food contamination, was correctly interpreted by Mercurialis and according to França (Trans. Royal Soc. Trop. Med. and Hyg., May, 1921) Gabriel Soares de Souza in 1587 stated that flies suck poisons from sores (*Frambœsia tropica*) then leave them in abrasions on healthy persons, thus infecting many people. About 1666 Sydenham expressed the belief that if house flies are abundant in the summer the autumn will be unhealthy.

Although much circumstantial evidence had accumulated against flies as carriers of infection prior to the announcement of the germ theory by Pasteur in 1877-1881, the first microscopic evidence was apparently not forthcoming until 1869 when Raimbert isolated the germ of anthrax from flies experimentally exposed to the cadavers of animals dead of anthrax. Raimbert also inoculated a guinea-pig with a proboscis, two wings and four legs of a fly, and a second one with a wing and two legs, resulting in the death of both animals. In 1886 Tizzoni and Cattini isolated virulent germs of cholera from flies caught in hospital wards in Bologna. According to L. O. Howard, Leidy in 1871 believed that house flies were responsible for the spread of hospital gangrene during the Civil War. It was not until the Spanish-American War in 1898 that the real menace of the fly became evident as indicated by the following quotation from an article by Veeder in the Medical Record of September 17, 1898, viz.:

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[1] Nuttall, G. H. F., and Jepson, F. P., 1909. The part played by *Musca domestica* and allied (non-biting) flies in the spread of infective diseases. Reports to the local Government Board of Public Health and Medical Subjects. (New Series No. 16.) London.

> "To clinch the argument, and apparently to leave no loophole for escape, I have made cultures of bacteria from fly tracks and from the excrement of flies, and there seems to be not the slightest difficulty in so doing. Indeed the evidence of every sort is so clear that I have about reached the conclusion that the conveyance of infection in the manner indicated is the chief factor in decimating the army."

The following quotation from routine orders (846, April 16, 1917) concerning sanitation in the operations of the Fourth Army (British) is indicative of the importance in which fly control was held during the Great War:

> "1. The approach of warmer weather makes it imperative that all ranks should appreciate the necessity for taking every possible precaution to safeguard the health of the troops during the coming summer.
>
> "*It must be impressed upon all ranks that their comfort and immunity from preventable disease will depend upon the cleanliness of their surroundings, and more especially upon the destruction and non-accumulation of all matter which can attract or afford a breeding place for flies. Every man must do his share of this necessary work, and the responsibility for seeing that it is done must be extended down to the commanders of platoons and other small units.*
>
> "2. During the offensive of last year certain epidemic diseases gained a considerable hold, and there is good reason to believe that most formations which took part in the Battle of the Somme include men who are carriers of disease germs. The universal and conscientious observance of the rules of sanitation is, therefore, necessary, if an epidemic of a serious nature is to be warded off.
>
> "3. The diseases in question, the most prevalent of which is Dysentery, all belong to the so-called Enteric group. The germs which cause these diseases are spread through the feces and urine of patients—early cases, slight cases, convalescents and carriers. The diseases are literally caught by the swallowing of infected matter introduced into the mouth in water, or in food contaminated by flies, dust, mud or dirty hands. The sanitary measures detailed below all aim at the prevention of this swallowing of filth.
>
> "4. It is a breakdown of ordinary sanitation which is most to be feared and guarded against. When excreta lie exposed and are trodden about, when

flies swarm from latrines to cookhouses and to uncovered food, or when shell-holes water is the only water available, then infection is inevitable.

"5. If, on the other hand, the value and object of the sanitary measures and rules laid down in this order are correctly appreciated by all ranks, and if the sanitary organization of units is sound and efficient, preventable disease will be reduced to a minimum."

Typhoid Fever.—The causative organism (*Bacillus typhosus*) of typhoid fever belongs to the typhoid-dysentery group, and is found outside the human body "only in those situations where it could be more or less directly traced to an origin in the discharge of a typhoid patient or convalescent." Jordan[1] and others have shown that the life of this germ in the water of flowing streams is of comparatively short duration, and that multiplication does not ordinarily take place in water; indeed, a steady decline in numbers goes on. Infection caused by transmission through the air is exceedingly rare according to these authors, but soil, on the contrary, may become contaminated through buried human excrement, or otherwise, and continue to be a source of infection for a much longer time than water. Notwithstanding these facts, the majority of typhoid fever epidemics are traceable to water infection, but indicate fresh contamination and not one of long standing.

Within the human body the typhoid bacilli are found mainly in the intestine, also in the urinary bladder, and in the majority of cases in the blood stream. The bacilli are discharged from the body with the feces and the urine; and are often present in such discharges for a period of ten weeks, and in chronic carriers for years after recovery. An added source of danger is the presence of virulent bacilli in very light cases of typhoid fever, known as "walking typhoid," where little or no precaution is exercised.

The above facts aid in interpreting the rôle of flies in typhoid transmission. Flies are attracted by excrementous matter, as has already been stated, and thus contaminate their mouth parts and feet, which, if the feces contain virulent bacilli, must now fairly reek with filth and disease. Thus equipped the fly next makes its way to the dining room, grocery store, fruit stand, etc., depositing there on the human food the infective dejecta by means of its soiled proboscis and feet. Thus, during the Spanish American war, flies with lime-covered feet were actually seen crawling over the food of the soldiers. The whitened feet were the result of lime and filth collected from the camp latrines. The depredations of typhoid fever at that time really mark the beginning of the widespread campaign against the house fly.

Jordan states:

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[1] Jordan, Edwin O., 1908. A Textbook of General Bacteriology, W. B. Saunders & Co., Philadelphia, 557 pp.

> "Not only may bacilli stick to the legs and wings of these insects, but if swallowed they may survive the passage of the alimentary tract. Typhoid bacilli have been isolated from house flies captured in houses in Chicago, in the neighborhood of badly kept privy vaults used by typhoid patients, and it has been shown experimentally that living bacilli may remain in or upon the body of flies for as long as twenty-three days after infection."

The writer's attention was at one time called to a series of sporadic cases of typhoid fever, plausibly traceable to flies, thus: a certain carpenter recently recovered from typhoid fever, resumed his work, making use of a box privy, such as is often used in connection with buildings under construction. In the immediate vicinity there lived a milk dealer, who, after washing his cans, placed them on the roof of a shed to drain. Flies are fond of milk, even highly diluted with water. The cases of typhoid fever in question were, on investigation, found to be customers of this particular dealer. The argument is good and reasonably conclusive.

The pollution of the waters of New York harbor has been made the subject of special study by Jackson.[1] In his report to the "Merchants' Association" of New York he shows that the sewage is not carried away by the tides, and "that at many points sewer outfalls have not been carried below the low-water mark, in consequence of which the solid matter from the sewers has been exposed on the shores." These deposits were found to be covered with flies, thus affording ample opportunity for the transmission of typhoid. It was, furthermore, found that the greater number of typhoid cases were found near the water front, and if the curve showing the prevalence of cases was set back to accord with the average time of infection, it coincided with the curve showing the prevalence of house flies. The fly curve, of course, also coincides with the temperature curve, but hot weather cannot account for the *dissemination* of the typhoid bacillus, nor for its presence.

Various authors at sundry times have shown experimentally that *Musca domestica* can carry *Bacillus typhosus* after having fed on contaminated material, both by contact with feet, proboscis and wings (Firth and Horrocks) and *via* the digestive tract (Faichnie).

Flies captured in houses occupied by typhoid fever cases have also been shown to be infected; thus Hamilton found *B. typhosus* in five out of eighteen flies captured under the above condition in Chicago, and Ficker made observations in Leipzig with similar results.

Dysentery.—There are at least two types of dysentery; of which one is caused by a bacillar organism, as in typhoid fever, and is known as *Bacillus dysenteriæ,* and the other variety is caused by a protozoan organism (Entameba) known as *Entamœba histolytica.* The former variety is known to be the prevalent type in temperate climates, while the latter is common in the Orient. The causative organism of both is found in great numbers in the stools of patients. The mode of infection is much the same as in typhoid fever.

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[1] Jackson, Daniel D., 1908. Pollution of New York harbor as a menace to health by the dissemination of intestinal diseases through the agency of the common house fly. Report to the Water Pollution Committee of New York City.

Summer Diarrhea in Infants.—A type of *Bacillus dysenteriæ* is present in the stools of infants suffering from summer complaint. Thousands of infants die every summer from this disease. Howard[1] states that in 1908 the number of death dues to summer complaint was 52,213, of which 44,521 were under two years. It is thus in the helpless months of the child's life that this disease is most dangerous. At this age the infants are greatly molested by flies (when these are present) attracted by milk vomits and especially stools, which often remain exposed for a long time and to which flies have free access. From these stools the flies travel to the child's face and mouth where they linger menacingly. Mothers who fail to protect their babies against the disease-bearing house fly are criminally exposing these innocents to deadly disease. Keep the baby well protected by screens, and if by accident a fly has fallen into the milk, it is better to throw it away. Furthermore, milk receptacles can easily be kept covered, and the fly in the milk is usually a sign of carelessness. Carefully protect nipples and nursing bottles against flies.

Nuttall in summing up the evidence against the house fly makes the following statement: "All authorities agree that flies rest under strong suspicion of serving as disseminators of diarrheal infection."

Tuberculosis.—Tuberculosis is caused by a specific organism, *Bacillus tuberculosis,* which may invade practically every organ and tissue of the human body. The lungs are commonly the seat of lesions, as are the intestines, the liver and the urogenital organs. The causative germs find their way outside the body in the sputum, the feces and the urine, depending on the location of the lesions.

In the study of transmission the considerable power of resistance which these bacilli possess is highly important. Dried phthisical sputum has been found to contain virulent bacilli after two months. Sputum has been found to contain living tubercle bacilli even after being allowed to putrefy for several weeks. The germicidal power of sunlight is very great, but according to Jordan[2] it requires from twenty to twenty-four hours' exposure to sunlight or even longer to kill the tubercle bacillus when present in sputum.

These facts are most important when, coupled with them, it is recognized that infection is commonly accomplished by way of the intestinal tract, with infected food introduced into the mouth. "Von Behring maintains that the vast majority of all cases of lung tuberculosis are of intestinal origin, and there is no doubt that pulmonary tuberculosis can originate from swallowing tubercle bacilli" (Jordan).

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[1] Howard, L. O., 1911. The house fly, disease carrier. F. A. Stokes Co., New York. xix + 312 pp.

[2] Jordan, Edwin O., 1908. *Loc. cit.*

It has been proved beyond doubt that the house fly can carry with it in its intestinal tract the *Bacillus tuberculosis*.

"The belief that flies (*Musca domestica*) which have fed on tubercular sputum may serve as carriers and disseminators of the tubercle bacillus first led Spillmann and Haushalter (1887) to investigate the problem. They examined such flies and also their excreta deposited on the walls and windows of a hospital ward, and were able to determine microscopically the presence of large numbers of tubercle bacilli, both in the intestines of the flies and their excrement" (Nuttall).

Howard quotes the following from a "paper by Dr. Frederick T. Lord (1904) of Boston":

"1. Flies may ingest tubercular sputum and excrete tubercle bacilli, the virulence of which may last for at least fifteen days.

"2. The danger of human infection from tubercular flyspecks is by the ingestion of the specks on the food. Spontaneous liberation of tubercle bacilli from flyspecks is unlikely. If mechanically disturbed, infection of the surrounding air may occur.

"As a corollary to these conclusions it is suggested that—

"3. Tubercular material (sputum, pus from discharging sinuses, fecal matter from patients with intestinal tuberculosis, etc.) should be carefully protected from flies, lest they act as disseminators of the tubercle bacilli.

"4. During the fly season greater attention should be paid to the screening of rooms and hospital wards containing patients with tuberculosis, and laboratories where tubercular material is examined.

"5. As these precautions would not eliminate fly infection by patients at large, foodstuffs should be protected from the flies which may already have ingested tubercular material."

The investigations by Dr. Ch. André of the University of Lyons were reported at the Anti-Tuberculosis Congress at Washington, 1908, viz.:

"Flies are active agents in the dissemination of Koch's bacillus because they are constantly going back and forth between contagious sputa and feces, and foodstuffs, especially meat, fruit, milk, etc., which they pollute by contact with their feet, and especially with their excretions.

"The experimental researches of the author show the following:

"1. Flies caught in the open air do not contain any acid-fast bacilli that could be mistaken for the bacillus of Koch.

"2. Flies that have been fed on sputum evacuate considerable quantities of bacilli in their excretions. The bacilli appear six hours after ingestion of the sputum, and some may be found as long as five days later. These flies, therefore, have plenty of time to carry these bacilli to a great distance, and to contaminate food in houses apparently protected from contagion, because not inhabited by a consumptive.

"3. Food polluted by flies that have fed on sputa contains infective bacilli and produces tuberculosis in the guinea-pigs.

"4. Flies readily absorb bacilli contained in dry dust.

"5. Flies caught at random in a hospital ward produced tuberculosis in the guinea-pig.

"*Practical conclusions.*—The sputa and feces of tuberculosis subjects must be disinfected; flies should be destroyed as completely as possible; foodstuffs should be protected by means of covers made of wire gauze."

Asiatic Cholera.—Asiatic cholera, as the name implies, is endemic in Asia (India), but has spread over the larger part of the world during the past century, becoming endemic in Africa and Europe. The disease relates to the intestinal tract, and is of bacterial origin (*Spirillum choleræ*). The cholera spirillum leaves the body with the stools, and infection is traceable to this source. "Upon the surface of vegetables and fruits kept in a cool moist place, experiments have shown that the spirillum may retain its vitality for from four to seven days" (Jordan).

Cholera was among the first diseases with which the house fly was associated as a carrier, and the experimental evidence is truly convincing. Tizzoni and Cattini in Bologna in 1886 isolated cholera vibrios from flies caught in cholera wards. Simmonds in 1892 captured flies in the post-mortem morgue in Hamburg and isolated cholera vibrios from these in large numbers.

There remains no doubt that flies are important carriers of cholera, and that bodies dead of cholera, stools and vomits of patients, should be protected from flies, and that foods should be most carefully screened.

Frambœsia (tropical ulcer or yaws) is caused by *Spirochæta pertenuis.* The disease is widely distributed in the tropics. The spirochætes are found in the superficial ulcers on the hands, face, feet and other parts of the body. The following quotation from Nuttall and Jepson[1] is convincing enough that *Musca domestica* is amply able to transmit this disease:

"Castellani (1907) tested the matter of the fly transmission of yaws by experimental methods. He allowed *M. domestica* to feed (1) upon yaws material (scraping from slightly ulcerated papules), and (2) upon semi-ulcerated papules on the skin of these yaws patients. In both cases he was able to discover the *Spirochaeta pertenuis* in microscopic preparations made from the flies' mouth parts and legs. Furthermore, he allowed *M. domestica* to feed on yaws material (1 and 2 as above) and afterwards transferred them to scarified areas upon the eyebrows of monkeys. Of 15 monkeys thus experimented upon three developed yaws papules at the places which had been contaminated by the flies."

Ophthalmia.—In commenting on ophthalmia as carried by flies Howard[2] has the following to say:

"Dr. Lucien Howe of Buffalo informed the writer (Howard) that in his opinion the ophthalmia of the Egyptians is also transferred by flies and presumably by the house fly, and referred the writer (Howard) to a paper which he read before the Seventh International Congress of Ophthalmology at Wiesbaden in 1888. He referred to the extraordinary prevalence of purulent ophthalmia among the natives up and down the river Nile and to the extraordinary abundance of the flies in that country. He spoke of the dirty habits of the natives and their remarkable indifference to the visits of flies, not only children, but adults, allowing flies to settle in swarms about their eyes, sucking the secretions, and never making any attempt to drive them away. Doctor Howe called attention to the fact that the number of cases of this eye disease always increases when the flies are present in the greatest numbers and the eye trouble is most prevalent in the place where the flies are most numerous. In the desert, where flies are absent, eyes as a rule are unaffected. He made an examination of the flies captured upon diseased eyes and found on their feet bacteria which were similar to those found in the conjunctival secretions. Flies captured in Egypt swarming about the eyes of ophthalmia patients and sent to Washington, D. C., were identified as *Musca domestica*."

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[1] Nuttall and Jepson, 1909. *Loc. cit.*

[2] Howard, L. O., 1911. *Loc. cit.*

Eggs of Parasitic Worms.—The most extensive and careful work on the dispersal of eggs of parasitic worms by the house fly has been done by Nicoll[1] and the following is a summary of his investigations in that respect. Flies feed readily upon infective material such as excrement laden with eggs from parasitic worms and even upon evacuated worms. Eggs may be conveyed by flies from excrement to food in two ways, namely on the external surface of their body and in their intestines. The latter mode is practicable only when the diameter of the eggs is under .05 mm. Eggs with a diameter of up to .09 mm. may be conveyed on the external surface; however, these adhering eggs are usually gotten rid of by the fly within a short time, while those harbored in the intestine may remain there for two days or longer.

The eggs may remain alive and subsequently cause infection in either of these ways; however, this depends on their resisting powers. It was found that material containing eggs of parasites, and in particular ripe segments of tapeworms, remain a source of infection through flies as long as two weeks.

The eggs of the following parasitic worms were shown experimentally to be capable of transmission by *Musca domestica: Tænia solium, Tænia serrata, Tænia marginata, Hymenolepis nana, Dipylidium caninum, Dibothriocephalus latus* (?), *Oxyuris vermicularis, Trichuris* (*Trichocephalus*) *trichiurus*, both internally and externally, *Necator americanus, Ankylostoma caninum, Sclerostomum equinum, Ascaris megalocephala, Toxascaris limbata* (*Ascaris canis* e. p.), *Hymenolepis diminuta* externally only. No trematode parasites were experimented with and the observations of Stiles that the larval fly can ingest Ascarid eggs and pass them on to the adult fly was not confirmed.

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[1] Nicoll, William (1911). "On the part played by Flies in the Dispersal of the Eggs of Parasitic Worms." Reports to the Local Government Board on Public Health and Medical Subjects (New Series, No. 53). Further Reports (No. 4) on Flies as Carriers of Infection. London.

Intestinal Protozoa.—Roubaud[1] found that the cysts of *Entamœba coli, Entamœba histolytica* and *Giardia intestinalis* passed through the intestine of the fly uninjured and that free amebæ (both *coli* and *histolytic*) when fed to flies were found dead in the fly's intestine in less than an hour. Root[2] found motile *Chilomastix mesnili* in a fly's feces seven minutes after it had fed on a stool containing them.

Murrina.—Murrina is a fatal type of trypanosomiasis of horses and mules in Panama and the United States. It is caused by *Trypanosoma hippicum* Darling and shown by Darling[3] to be transmitted mechanically by houseflies from sick animals to well ones by contact with blood from skin lesions and also in a number of other ways.

Summer Sores in Horses.—An examination of certain persistent ulcerations on the lower portions of the bodies of horses and which have a tendency to disappear during colder weather, may reveal the presence of larval nematode worms belonging to the genus *Harbronema* measuring from 1 to 1.5 mm. in length. The presence of such worms in sores on the eyes is termed *habronemic conjunctivitis.* The adults of these worms such as *Habronema muscæ* (Carter) measuring from 8 to 14 mm. in length in the male and 13 to 22 mm. in the female occur in the stomach of the horse where they lay their eggs which pass out with the feces. The newly hatched larvæ find their way into the bodies of fly larvæ which are evidently true intermediary hosts and in which further development occurs. The flies resulting from such larvæ may contain a number of such worms (from 1 to 20) in their bodies, often the head. According to Ransom[4] the infection of horses with *H. muscæ* is apparently brought about by the swallowing of infested flies. The sores above mentioned are evidently the result of larvæ entering lesions while the animals are lying down in infected manure.

Fowl tæniasis.—Domestic fowls are commonly infested with tapeworms and the extent to which this may occur is well illustrated in Fig. 125. Several species of tapeworms inhabit the intestines of fowls, but although Grassi and Rovelli[5] as early as 1886 had made observations concerning their development, it was not until 1916 that strong experimental evidence was published by Gutberlet[1] proving that the housefly (*Musca domestica*) was an intermediary host.

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[1] Roubaud, E., 1918. Le rôle de mouche dans la dispersion des amibes dysenteriques et autre protozoaires intestinaux. Bul. Soc. Path. Exot., Vol. XI, pp. 166-171.

[2] Root, F. M., 1921. Experiments on the carriage of intestinal protozoa of man by flies. Amer. Journ. of Hyg., Vol. 1, No. 2, pp. 131-153.

[3] Darling, S. T., 1912. Murrina, a trypanosomal disease of horses in Panama, and the means used in controlling an outbreak. Trans. Fifteenth Internat. Cong. Hyg. and Demog., Washington. Vol. V, Part II, pp. 619-631.

[4] Ransom, B. H., 1913. The life history of *Habronema muscæ* (Carter), a parasite of the horse transmitted by the house fly. U. S. Dept. of Agric., B. A. S. Bull. 163, 36 pp.

[5] Grassi, B., and Rovelli, G., 1889. Embryologische Forschungen an Cestoden. Centralbl. Bakt. and Parasitenk., 5:370-377: 401-410. Cited by Gutberlet.

The most important of the fowl tapeworms is *Choanotœnia infundibuliformis* (Goese). It measures from 50 to 200 mm. in length. The scolex is small and rounded measuring about 0.4 mm. in width. The rostellum is armed with a single row of 16 to 20 hooks. The cysts found in the house fly are oval in shape and measure about 220 μ in length by 120 μ in diameter. Gutberlet infected the adult flies by feeding them on liquids which were infected with tapeworm "eggs," and it is assumed that fly larvæ breeding in infected fowl droppings would become similarly infected.

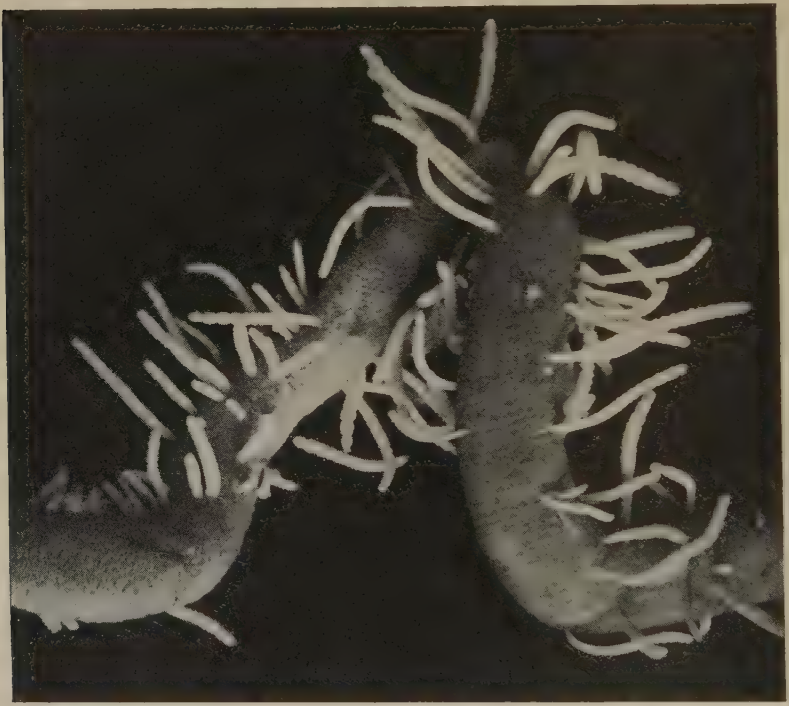

Fig. 125.—Showing segment of intestine (inside out) of fowl infested with numerous tapeworms (*Choanotœnia infundibuliformis*).

Davaniea cesticillus (Molin) according to Gutberlet also has the house fly as its host and *Hymenolepsis carioca* (Magal.) has *Stomoxys calcitrans* the stable fly (see Chapter XV) as its host.

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[1] Gutberlet, J. E., 1916. Morphology of adult and larval cestodes of poultry. Trans. Amer. Micro. Soc., Vol. 35, No. 1, pp. 23-44 (2 plates).

Other Species of Musca.—Although *Musca domestica* Linn. is commonly regarded as a cosmopolitan species and although all house flies having that general appearance are generally regarded as members of that species, it is pointed out by Patton[1] that there are distinct differences both in morphology and habits. He points out "that both sexes of one of the species of *Musca* found in the tropics are very similar to *Musca domestica* is quite true but when we come to compare the male with the male of *domestica,* we find that the front of the former is at least half as wide as that of the latter. . . . I have yet to see a specimen of *domestica* from Great Britain with a front as narrow as that of this tropical form." (*Musca nebulo* Fabr.) Patton divides the genus *Musca* into two natural groups, (1) the housefly group, and (2) the wild species or exclusively outdoor group. The latter, he states, largely if not entirely feed on blood and serous and pustular discharges, breeding in cow-dung. In the first group Patton includes besides *Musca domestica* Linn., the Indian species *M. nebulo* Fabr., *M. domestica* L. (atypical) and *M. humilis* Wied. In the second group he lists twelve Indian species, among them *M. pumila* Macq., *M. ventrosa* Wied., *M. pattoni* Austen and *M. bezzii* Patton and Cragg. *Musca corvina* Fabr., both *ovipara* and *vivipara,* is a European blood-sucking species and the latter subspecies together with *M. bezzii* are larviparous.

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[1] Patton, W. S., 1922. Notes on the species of the Genus Musca, Linnæus—Part I. Bull. Ento. Res., Vol. XII, Part 4, pp. 411-426.

CHAPTER XIV

HOUSE FLY CONTROL

Essentials of Control.—Effective fly control is based on a knowledge of the habits and life history of the insect. First find the breeding places and then apply the remedy. What would you think of a town whose business streets were lined with flytraps, for the baiting and general operation of which a man was paid a monthly salary, and the alleys of this same town were lined with open garbage cans and other sundry receptacles literally wriggling with maggots and about which there was no concern? You could follow the fly, if you took the time, as it crawls out of its filthy place of birth through the open back door of the "delicatessen" into the kitchen, where it "sports" around on the cottage cheese before this food is put into the glass, fly-protected showcase, and leisurely the fly wends it way toward the front door and out upon the sidewalk with a customer and because of its insatiable desire for more food and company it finds it way into the flytrap. No doubt the newspapers and city officials applaud the work of the club (or perhaps it was the City Health Department) that started the campaign "for its most effective and excellent service to the city in destroying sixteen pints of flies already and the work has just begun." The flies, of course, have been captured after the food has been contaminated and the damage has been done. It is quite true that work in the alleys and backyards is not quite so spectacular and the result is "only" in better health for the town, i.e., the results cannot be counted in so many pints of flies captured. Sanitation is after all only applied common sense with a scientific backing to insure accuracy and efficiency. The presence of flies always denotes defective sanitation. The defective disposal of manures, garbage, sewage, slops, food wastes, ensilage, brewer's grain, spent hops, wet mash, dead animals, etc., is responsible for gross fly breeding.

Sanitary Stable Construction.—Since the principal rural breeding places of the house fly are usually found in and about stables, particular attention must be paid such situations with special reference to the disposal of manures. In the first place the stable should have a concrete floor. A very practical consideration of this subject is to be found in Bulletin No. 97, North Dakota Agricultural Experiment Station, from which the following suggestions are largely taken. Although higher than wood in first cost, concrete meets the requirements of a good floor better than any other available material. Concrete floors, according to the bulletin mentioned, are considered best for several reasons.

> "(1) They are economical because they are durable. Wooden floors last from three to five years with a maximum of ten years, if of the best construction, while the durability of concrete floors equals that of the building. (2) They save labor because of their evenness, which permits of thorough and easy cleaning. (3) They are sanitary not only because they can be kept clean, but because they are easily drained and are water-tight enough to exclude ground water and prevent the liquid manure from leaching into and polluting the soil.
>
> "The chief objection to concrete floors are that they are cold and slippery. To the first may be replied that in reality concrete is no colder than wood subjected to the same temperature but on account of being a better conductor of heat concrete carries away the bodily heat of the animal faster if they come in direct contact with it. This is not a serious objection, for even wood is too cold for animals to lie on without bedding, which should be supplied liberally on any floor. Straw is a poor conductor of heat and if a sufficient amount of bedding is used, the bodily heat of the animals will be retained as well on concrete as on wood, which is apt to be more or less wet or soggy. A generous use of bedding is desirable not only because it adds to the comfort of the animals, but because of the increased amount of manure which in turn means increased fertility of the farm. The objection of slipperiness may be overcome by making the wearing surface scored or grooved into blocks before it has hardened. These sections made from 4 to 6 inches square furnish a good foothold for the animals and make a very neat appearance.
>
> "The floor should be raised about one foot above the surface of the ground to insure drainage. If earth has been filled in to secure this elevation, it must be thoroughly compacted so as to prevent uneven settling and subsequent cracking of the floor. It is a good practice to make the desired fill as soon as the foundation is completed because it can be done more conveniently at that time and the fill will have proper time to settle before the floor is put on.
>
> "Concrete stable floors should be about 5 inches thick. The lower 4 inches should be made of concrete in the proportion of one part cement, 2½ parts clean, coarse sand and five parts screened gravel or broken stone and finished before the concrete has set, with a one-inch mortar of one part Portland cement to two parts clean and coarse, but sharp sand. If the sand or cement are not first-class, this proportion had best be changed, for horse barns at least, to one part cement to 1½ parts sand.
>
> "Before laying the concrete a foundation of porous material, such as cinders or gravel, should be spread evenly on the surface and thoroughly tamped down. The depth of this foundation will depend upon the drainage of the soil but where a fill of one foot of earth has been provided, as previously described, this foundation need not be more than four inches thick."

In constructing a concrete floor provision must be made to carry away the urine from the animals and water used in cleansing the floors and stalls. Suggestions from the above-named bulletin are here again useful, namely, the stall floors should be given a 1 inch drop from the manger to the manure gutter, which latter should be

> "6 inches deep and 14 inches wide. In order to facilitate the drainage away of the liquids a 3-inch U-shaped channel is sometimes made in the bottom of the gutter next to the manure alley, but this is not necessary where a slope is given the gutter bottom. The gutter should be given a uniform fall of 3 inches to 100 feet and the floor of the manure alley should have a slope towards the gutter of 1 inch to 10 feet. A small water-tight liquid manure cistern may be provided outside the barn into which the gutter drains, but if a manure shed is used the cistern should be in the shed. The gutter should be connected to the cistern by means of a drain pipe effectively trapped like the soil pipe in a house and so arranged that the trap may be easily cleaned."

In cities with sewer facilities connection is made directly with the sewer, dispensing with the manure cistern.

Often the concrete stall floors are covered with wood so that the animals do not come in direct contact with the concrete. If such superfloors are provided, they should be made of heavy two-inch strips three inches wide and as long as the stall. The strips are fastened together by crosspieces (ordinarily flat iron strips) so that a space of about one half inch remains between the strips. To facilitate ease of handling it is strongly recommended that the floor be made in two long pieces, each half the width of the stall, and fitting closely where they join. In this way the superfloor can be lifted up while the concrete is being cleaned; the crevices between the wood strips can be readily freed from manure by means of a heavy stream of water or iron rod. If the crevices are not also frequently cleaned, fly larvæ will develop there very readily.

Manure and odors of manure will attract the female flies even though the stable is somewhat dark. The writer believes that the small extra cost of screening a stable against flies is a good investment since it not only lessens the opportunity for flies to breed but also adds to the comfort of the animals.

Disposal of Manures.—Wherever horse manure is piled up and accessible to flies the opportunity is given for them to breed. In the preceding chapter it was pointed out that an average manure pile weighing about half a ton, after an exposure of only four days harbored approximately 450,000 fly larvæ. As before stated it requires only about four days for the larvæ to reach full growth, after which they begin to migrate into the drier portions of the heap and crawl out into nearby débris, beneath platforms, etc. It is therefore imperative, if fly breeding is to be prevented, that manure be protected against flies from the beginning, or that it be rendered undesirable to flies, or that it be otherwise disposed of.

Under ordinary rural conditions the most practical method is to remove the manure to the field daily. A cart may be used for this purpose; it is daily backed up against the stable doorway, the manure thrown in and carted away at once to a field where it is scattered. This saves much time in handling and is sound agricultural practice. Since moisture and warmth are both necessary for the development of fly larvæ the scattered manure cannot serve this purpose.

The Wisconsin Bulletin No. 221 states:

> "Manure is never so valuable as when perfectly fresh, for it is impossible under the best system of management to prevent all loss of its fertilizing ingredients. For this reason, whenever possible, the manure should be hauled directly to the field and spread. The system saves time and labor as it involves handling but once. The manure will be leached by the rain and snow, nevertheless the soluble portion will be carried into the soil, where it is needed. When spread in a thin layer, it will not heat, so there will be no loss from hot fermentation, and where manure simply dries out when spread on the ground there is no loss of valuable constituents."

A manure spreader is a valuable part of every farm equipment.

The question is raised,—will not chickens eat the maggots and thus keep in check the flies in manure piled up in the barnyard? It must be considered that manure piled up sufficiently deep to permit fly larvæ to develop in it does not permit chickens to scratch their way through the heap and consequently they can only destroy a small fraction of the larvæ; and where the manure pile is low enough for chickens to scratch it over and over, the fly larvæ would not develop anyway owing to the dryness and lack of heat. Furthermore, it is not safe to permit chickens to feed on maggots owing to the fact that the larva of a common and dangerous poultry tapeworm (Fig. 125) is commonly harbored by these insects. Farmers and gardeners who wish to use "rotted" manure for fertilizing purposes should screen the heap until the "rotting" process is well under way, when fly breeding will be reduced to a minimum, or, as has already been suggested, the manure may be placed in trenches and covered with lime and earth whenever fresh manure is added or it may be stored in fly-tight composting pits.

Manure Wastage.—Under the present system of manure disposal, namely, piling it in the barnyard (Fig. 117), there is an enormous loss of manurial value due to leaching and fermentation, estimated at from 25 to 50 per cent. The Cornell University Experiment Station has carried on investigations which show the loss of the valuable plant food when disposed of in the usual exposed manner for six months. When the manure was tested it was found that the horse manure had lost 57 per cent and the cow manure 49 per cent in gross weight and the loss in value based on plant food (nitrogen, phosphorus, and potassium) amounted to 65 per cent for the horse manure and 23 per cent for the cow manure. When manure wet with urine is thrown from the stable on to the heap it contains about 75 per cent water which holds most of the plant food. Exposed to leaching rains and weather the liquid sinks into the ground beneath or flows away. Thus not only does the barnyard manure pile result in flies but also in serious loss to the farmer.

To insure against the loss of liquids and multiplication of flies in the barn, attention must be paid to stall floors to make them tight and to a means of conserving the urine from the animals by means of suitable gutters as already explained.

Manure Bins.—Under city conditions it is ordinarily impracticable to remove manure from the premises daily, hence it must be stored temporarily in special receptacles or bins. Heretofore, stress has been laid on *fly-tight* receptacles, but unless exceptional care is exercised in operating such receptacles, they actually become fly-breeding cages. The writer early recognized this difficulty and suggested a remedy as below described.

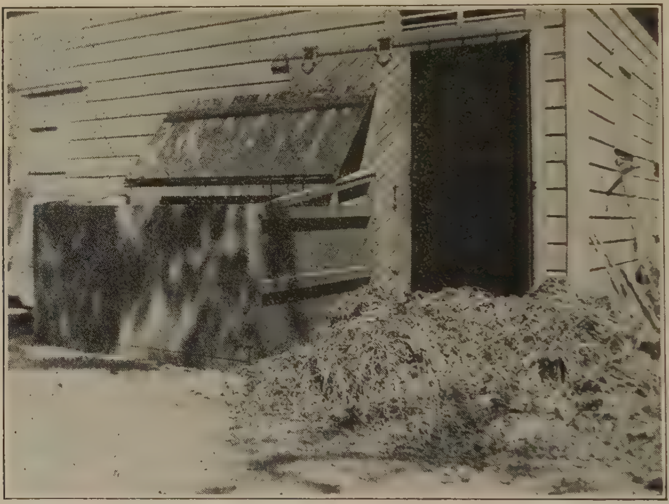


Fig. 126.—Manure bin in a position to become a fly breeding cage, instead of a fly preventative. It is suggested that the lid be permanently closed, and an opening made directly from the stable into the bin. The manure pile adjoining the bin illustrates the manner of disposal before the bin was built.

Figure 126 illustrates a manure bin of the earlier type. The manure pile near by illustrates the manner of disposal before the bin was erected. In this case the lid of the bin must be kept open while the manure is being transferred to it from the stable, and during this time flies enter the box in numbers, and when the lid is closed they are trapped, deposit their eggs and soon the manure is reeking with maggots and if the bin is not cleaned out before the expiration of nine or ten days, myriads of flies emerge and are liberated when the lid is opened.

The bin is built on a concrete floor to prevent rats from nesting underneath, it is painted with creosote inside and ventilation is provided for at both ends by means of screened openings. The screen should be of copper wire to prevent rapid rusting. The front of the bin is provided with a hinged door which lifts up so that the manure can easily be removed. The dimensions are approximately as follows: length, 8 feet; width, 4 feet; height in front, 4 feet; height in back, 5 feet.

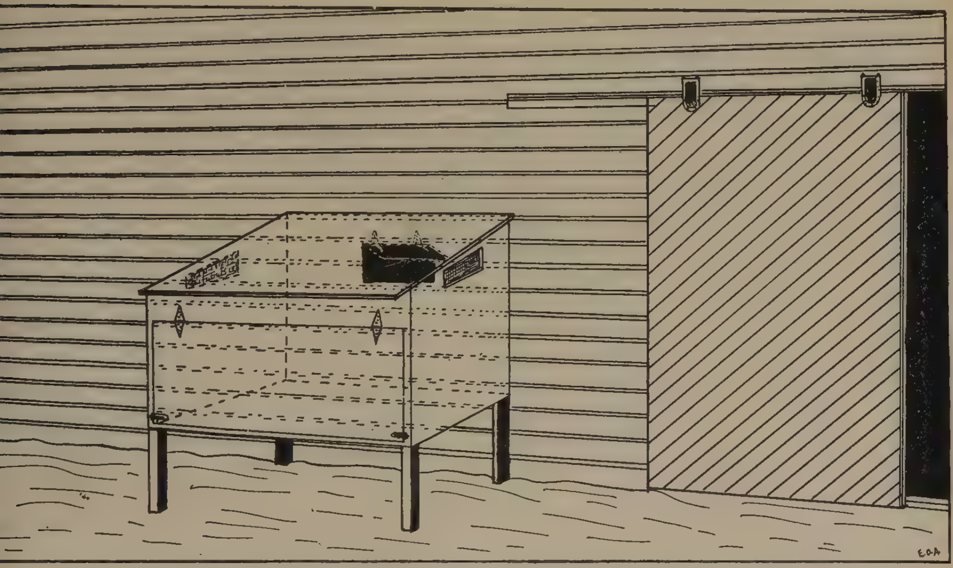


Fig. 127.—A properly constructed manure bin with opening directly from stable into bin. May or may not be elevated on legs to facilitate removal of manure to wagon. Size of bin depends on number of horses and frequency of manure removal.

The size of the bin, or composting pit if this is used, depends, of course, on the number of horses stabled and length of time during which the manure remains in storage. It may be estimated that the average horse produces 1½ cubic feet of manure per day, including bedding.

To prevent the bin from becoming a fly-breeding cage, the writer recommends that the top be permanently closed, i.e., without a lid, and that the manure be thrown into the bin directly from the stable through a small door cut through the side of the stable into the bin near the top of the same (Fig. 127). This opening can easily be provided with a small sliding screened door. Furthermore, the bin should be built so that the small door last mentioned can be located in a dark part of the stable, thus further preventing flies from entering the bin. At a small added cost flytraps can be attached at the ventilator ends of the bin in such a manner that chance flies in the box will enter these. Because the flies respond to the light they will naturally gather at the ventilator ends and if the traps are baited with some material attractive to the flies, there is an added inducement to enter.

Composting Pits.—Composting pits are frequently used on country estates and truck gardens where quantities of rotted manure are used for fertilizing purposes. Such pits are usually made of concrete and covered with wood, all carefully constructed to exclude flies and mosquitoes, which latter may breed in the liquids collected in the sump. A properly constructed composting pit enables one to preserve the urine, which is very valuable in addition to the more solid excreta.

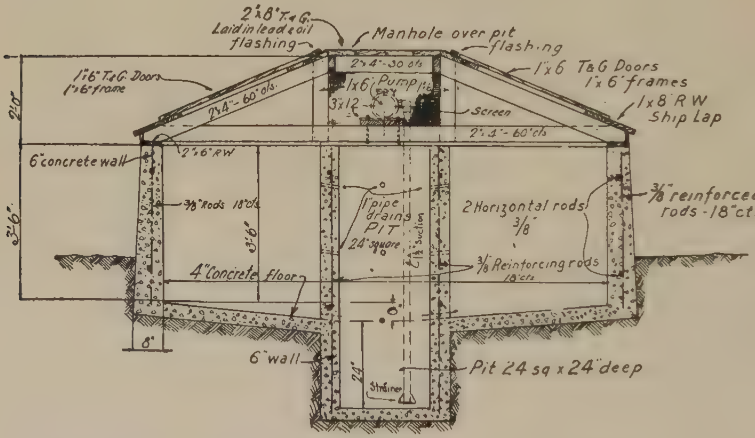


FIG. 128.—Cross-section of a concrete flyproof composting pit. (After Rosenthal in Advisory pamphlet on Camp Sanitation and Housing, Commission of Immigration and Housing of California.)

A cross-section of a composting pit is shown in the figure (Fig. 128). In this case a pump is shown, by means of which the urine and water are pumped out of the sump and returned to the manure from time to time. Water should be applied to the manure occasionally to prevent burning, which may otherwise destroy the salts so valuable in the fertilizer.

The size of the pit depends also on the number of horses stabled. A pit as shown in the figure with a length of sixty feet ought to store the manure from ten horses for a period of six months.

Compacting the Manure Pile.—If daily spreading, storage or other means are out of the question, then a fair degree of fly control can be accomplished by selecting a well drained open spot several hundred feet from the stable and build by daily additions a long, narrow, compact manure pile with straight sides. It will be found that the outside exposed parts dry out quickly and the inner parts become too hot for fly larvæ. If in addition to compacting the manure, the daily additions are put into a hole made in the old manure and covered over with the same, thus burying the fresh manure which is so attractive to flies, further control may be secured.

The Maggot Trap.—It has already been explained that fly larvæ respond to a migratory habit just prior to pupation. The maggot trap (Fig. 129) takes advantage of this habit, and consists of a wooden platform 20 feet long and 10 feet wide, supported on legs one foot high. Across the framework are nailed strips 10 feet long by 1¼ inches thick and one inch wide and one inch apart. Slatted sides 3 feet high may be added to hold manure in place. This platform is placed in a sort of concrete basin about 4 inches deep (concrete floor 22 feet long and 12 feet wide, with a rim 4 inches high and 4 inches thick) in which water is placed to a depth of ½ inch in the shallowest part. The basin floor is made to slope slightly toward one corner which is fitted with a 4-inch outlet pipe (plugged with wood when in use) so as to easily run off the water if necessary.

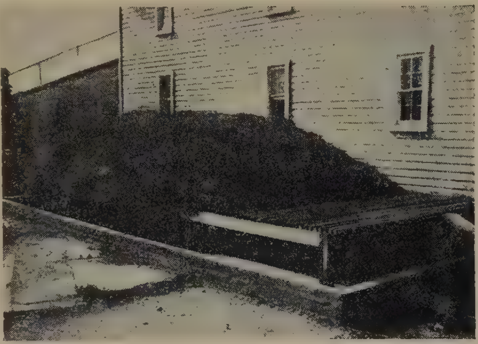


Fig. 129.—View of a maggot trap showing the concrete basin containing water in which larvæ are drowned and the wooden platform on which manure is heaped. (After Hutchinson, United States Department of Agriculture Bulletin 200.)

The manure is then dumped as usual directly from the stable upon the platform, with the precaution, however, that the manure must be sprinkled daily with enough water to moisten it thoroughly. Flies now deposit their eggs as usual and fly larvæ develop to the point when they are ready to migrate, and because of the moist condition of the entire pile leave it, drop into the water and are drowned. By the use of this method the Maryland State Agricultural Experiment Station reports a maggot destruction of 95.8 per cent for the three seasons 1914, 1915 and 1916. The close packing of the manure, the watering of the pile (using repeatedly the water in basin) and the return of leached materials to the manure tends to conserve the fertilizing value of the manure as already explained.

Chemical Treatment of Manure.—Although there is a strong popular demand for some chemical, which if applied to the manure will result in fly prevention, the writer does not enthuse over this method of control for several reasons; first, this scheme may be used as a substitute for the real sound principle of sanitation, cleaning up and keeping clean; and secondly, owing to the necessity for daily application there will certainly be neglect.

Ordinary applications of the usual insecticides are of little avail. The cheapest and at the same time the most effective preparations must be used two to five times as strong as when used against other insects because of the hardiness of fly larvæ, and furthermore, the larvæ cannot be reached easily, buried as they are in the bedding or manure. Broadly speaking, such chemicals may be either repellents, to prevent flies from laying eggs on the manure, such as creosote oil; or they may be contact poisons such as kerosene, chlorid of lime and borax; or they may be stomach poisons, for both larvæ and adults, such as arsenite of soda. From the practical standpoint aside from their use in fly control such chemicals should not impair the value of the manure as fertilizer. Furthermore, if poisons are used the manure may be dangerous to live stock.

Many chemicals have been tried by a score or more of investigators and several effective chemicals have been found which can be used economically and effectively.

Borax is recommended by the United States Department of Agriculture at the rate of 0.62 pounds to eight bushels of manure. In testing out the use of borax the New Jersey Experiment Station applied the following method:

> "The borough furnished each stable where the borax treatment was necessary with one or two large 30-gallon cans, one 10-quart watering pot and all the necessary borax for making treatments. The stablemen were instructed to sprinkle 2½ gallons of solution on the daily output of manure from one horse and to make this application every day. One ounce of borax to one cubic foot of manure will kill 90 per cent or more of the larvæ and inhibit the eggs from hatching, provided it is applied in solution and the larvæ and eggs come in contact with it. It was figured out that the average output from one horse is 1½ cubic feet of manure per day and that 2½ gallons of water containing 1½ ounces of borax should penetrate all parts of this amount of manure. The large stock cans held about 30 gallons of solution (18 ounces of borax) and this was sufficient to make 12 treatments for one horse. In making treatments it was noted that wet manure which had been soaked by rains, or when located in low wet areas was difficult to treat, for it was next to impossible to make any additional water (by sprinkling) penetrate the wet manure. When manure is in this condition, particularly in low wet areas, and contains numerous larvæ, it should be put on higher ground in order that it may dry out somewhat; or a thick layer of gravel or cinders placed under the manure in wet low areas will help considerably. Manure treated with borax is detrimental to some plants when the manure is used as a fertilizer, but, as far as known, it will not injure plants provided one

does not use over 15 tons of treated manure (not over one pound of borax for every 16 cubic feet) to the acre."

Borax is an excellent chemical to use on dirt stable floors, in privies, and on accumulations of fermenting matter which will not be used as fertilizer.

Hellebore (the powdered roots of *Veratrum album* and *V. viride*) is strongly recommended by the United States Department of Agriculture. It is used at the rate of ½ pound to 10 gallons of water, applied after stirring and standing 24 hours, to 10 cubic feet or 10 bushels of manure. No injury to plants seems to result when treated manure has been used as fertilizer. "The only possible objection to the use of hellebore seems to be the possibility of poisoning farm animals, as might happen if, for example, the barrel or tank in which the stock solution was prepared were left uncovered in an accessible place. It is quite safe to say that chickens will not be injured by pecking at hellebore-treated manure."

Arsenite of soda solution is very effective but is too dangerous for general use. The following formula for a stock solution is suggested: arsenite of soda, 4 pounds; molasses, 2 quarts; water, 50 gallons. The arsenite of soda is first dissolved in the water and the molasses is added to make the solution attractive to flies. It is used as a spray for manure piles. It is highly important that the solution be kept out of reach of children and live stock.

Creosote oil was used by the British during the late war in fly-control operations both on manures and on dead bodies. It was used at the rate of one gallon to the ton of manure and applied as a spray to each daily addition to the heap. It is said to be noninjurious to the fertilizing value of the manure, though this is doubtful. Creosote oil is also a good fly repellent when sprayed on beams, walls and floors of stables, or it may be applied to pieces of cloth and hung over entrances. It is said to have kept mess halls free from flies for from six to ten days.

Dust has considerable value in fly control. The writer found that very few flies bred in the manure from cavalry horses on duty along the Mexican border during the summer time when the droppings were thoroughly mixed with dust and disposed of in windrows a short distance from camp.

Kainit, pyroligneous acid, iron sulphate, copper sulphate, lime sulphur, sodium chlorid (table salt) and many other chemicals commonly recommended as of value in fly control have been found more or less useless.

Use of Manure on Lawns.—It frequently happens that veritable swarms of flies suddenly make their appearance on porches, windows and in the house for no obvious reason. This is frequently due to the application of comparatively fresh manure to lawns. Such manure is commonly infested with full-grown maggots or pupæ which in a few days after the fertilizer has been applied give rise to a pest of flies. It is, no doubt, wise to use old composted manure for this purpose or subject the manure to a thorough steaming or drenching with hot water at 195° F. (nearly boiling) before applying it to the lawn.

Two objections are commonly raised against this method of treatment, first, that the useful bacteria are destroyed, i.e., the manure may be rendered sterile; and, second, that all other desirable constituents are leached out by the water. Not all of the useful bacteria, by any means, are destroyed by the hot water and those remaining quickly multiply and soon render the manure as good as ever in this respect. In the second place, the leachings may be preserved quite easily by placing the manure to be treated in a shallow, tight box similar to those used by plasterers for mixing mortar, and adding a spigot in a hole with plug from which the leachings can be drawn and used as liquid manure.

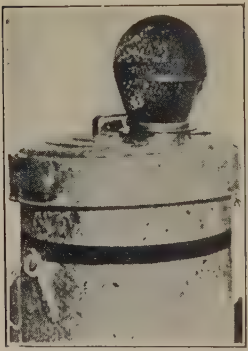


Fig. 130.—An effective combination garbage can and fly trap. (After Hodge.)

The above described method is also useful to mushroom growers who must use rotted manure in which certain species of fly larvæ, mites, etc., may occur in great numbers.

Railroad cars laden with manure are often sidetracked in or near communities and are responsible for swarms of flies. The writer has on several occasions recommended that the periphery of the entire carload be subjected to a treatment of live steam from the locomotive, with good results.

Garbage Cans.—The writer has been favorably impressed with the type of combined garbage can and flytrap invented by Professor C. F. Hodge. By his permission a diagram is here given (Fig. 130), together with his explanation of the same (see Nature and Culture, July, 1911), viz.:

> "The principle of operation is that hungry flies will crawl in toward the smell of food through any dark crack and, after feeding, will fly out toward the light. They enter the garbage can or other receptacle by smell, and attempt to leave by sight. It is necessary to have the cover about half an inch larger in diameter. Three pieces of sheet iron are soldered inside the rim, equidistant apart to hold it up, a crack, and keep it spaced out from the rim of the can about one-fourth of an inch all around. In a swill barrel, nails may be driven into the rim and bent over to hold the cover properly, *but direct light must not enter this crack.* Cut a hole in the cover at least three inches in diameter and fasten the trap over this opening according to plain directions sent out with each trap. With everything in the way of waste food material put into this receptacle, you establish a 'focus,' a 'vacuum cleaner' for flies, and properly managed, this will prove exterminative."

Where ordinary garbage cans are used, and certainly every household should possess a garbage receptacle that can be tightly closed against flies (unless above plan is followed), it is strongly urged that all liquids be drained from the refuse before disposing of it and that the solids be wrapped in a newspaper before placing in the can. In this way fly breeding in garbage may be effectually prevented and an act of mercy is done the scavenger and others as well.

Garbage Collection and Disposal.—Not only must the garbage can and its proper use be insisted upon in this connection, but also the proper collection of the garbage by the scavenger. Few sights are more disgusting than that of an open garbage wagon reeking with its load of vile-smelling offal and swarming with flies. During the strawberry season it is a matter of daily occurrence in many cities to see the garbage wagon (Fig. 131) traveling side by side with the strawberry wagon, flies crossing from one to the other without restriction. This is certainly revolting if not also a menace to health. Municipal collection of garbage in properly constructed city-owned garbage wagons is the only solution of the present outrageous common system.

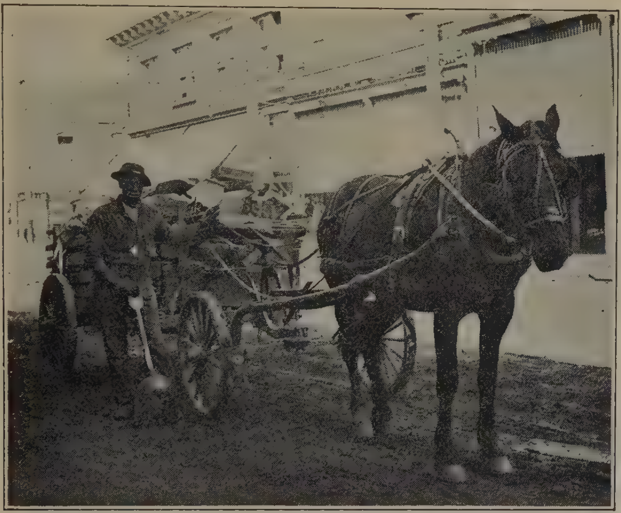


Fig. 131.—Flies are commonly and abundantly distributed through the community by poorly arranged garbage wagons. Properly constructed, closed, city-owned and regulated garbage wagons must take the place of the above pernicious system.

No more sanitary way of disposing of garbage can be devised than that of incineration. The garbage *dump* will always be a fly producer, particularly if it receives manures and moist offal.

City Dumps.—City dumps are very commonly the source of numerous flies. Flies were noticeably abundant in and about Newport News, Va., by May 1, 1918, and for the week ending May 25 it was reported that the restaurants were seriously infested by them and they were numerous in all neighboring army camps. Camp Stuart particularly was well within the range of flight of flies originating in and about the city, thus within a distance of one-half mile of this camp the city of Newport News maintained a series of garbage dumps comprising a combined area of about five acres. The dump in the vicinity of the gas house extended for a distance of about one long city block on both sides of the street, nearly blocking the same at several points. Near Boat Harbor the garbage extended to the street car tracks. The "gas house" dump not only received dead fish and all manner of perishable garbage but also all the night soil from city privies estimated at 900 at the time by the U. S. Public Health Service. Flies swarmed over all and maggots beyond calculation pervaded the mass. The stench was indescribable.

The situation was soon remedied by liberally applying crude oil with spray pumps and setting fire to the dumps which shrank little by little before the flames and fly breeding quickly ceased. Thereafter all dumping of garbage was done at certain points and incineration was a continued process. The U. S. Public Health Service as rapidly as possible furnished sanitary privies and the night soil systematically collected was emptied into the sewer.

Piggeries.—While on duty as a Sanitary Officer at the Port of Embarkation, Newport News, Va., in 1918 a very severe outbreak of flies occurred at the Embarkation Hospital. Although some fly breeding was discovered in several of the corrals this was relatively unimportant, the real cause for the swarms of flies was discovered in a group of pig pens several hundred feet distance across an open narrow salt marsh. The owner of the swine collected the kitchen wastes, etc., from the hospital, in such quantities that every available barrel, box, tub and pail was full and literally running over with swill and similar garbage. These numerous receptacles both inside and out and the troughs and filth of the pens were literally infested with a creeping mass of maggots. After the owner of these numerous broods of flies had been enlightened as to the nature of the maggots, he consented to any means of control necessary. The epidemic of flies was quickly checked by a combination of two methods: first, a detail of oilers from the Malaria Drainage Detachment was ordered to the piggery and liberal quantities of oil applied to every receptacle, including the ground beneath, and all the pens, resulting in a great slaughter of maggots; and, secondly, numerous saucers containing a mixture of formaldehyde, canned milk and water (formalin 1 pint, canned milk 1 can, sugar 1 pound, water 3 gallons) were placed in front of the wards with the result that the ground in the immediate vicinity of the saucers was soon black with dead flies. The fly epidemic was quickly checked. This experience led to a more careful survey of similar conditions with the result that over fifty pig pens were found within a distance corresponding to about two city blocks and easily within a half mile of Camp Stuart. These pens were all in an indescribably filthy condition and literally alive with flies and maggots.

The addition of a small quantity of turpentine to the swill serves to repel flies to a certain extent and thus limits breeding; however, the writer has found that much of the fly breeding in piggeries is due to slops and feed in general being pushed out of the troughs and accumulating around them, thus forming an excellent fly pabulum, a mixture of hog manure, slop and urine. The liberal use of concrete for floors, troughs and wallows and frequent flushing out with a hose will greatly reduce the crop of flies which one usually encounters at a piggery during the summer time.

Dairies.—The presence of numerous flies about the premises of a certified dairy (Marin County, Calif.) which upon inspection was found to be very clean and otherwise in excellent condition with no evident immediate reason for the presence of the flies, was a matter of no small importance under the circumstances. The trouble was located in a field a few hundred feet from the dairy barn where numerous *heaps* of waste brewers' grain (used as cattle feed during late summer and autumn) had been hauled and dumped. Each heap was a veritable wriggling mass of house-fly maggots. Liberal applications of fuel oil to the heaps soon destroyed the source and further waste feed was spread out in a thin layer to facilitate rapid drying and thus to defeat fly breeding. The epidemic of flies was soon brought under control. Fly breeding about dairies is frequently traceable to accumulations of waste feed about the troughs, the waste becoming mixed with feces and urine. Thus bad conditions may arise in spite of the proper disposal of manure.

Lawn Clippings.—Grass clippings from lawns around public buildings are often dumped in heaps near by. Hot weather soon produces a vile smelling, decomposing, hot mass of grass which is very attractive to flies and within a few days numerous maggots, particularly housefly, may be found inhabiting the mass. Thus, again, in spite of the absence of manure and garbage there may be a veritable plague of flies. The method of control is obvious, namely the clippings should be spread out thinly in order to dry out and may be then burned or otherwise disposed of.

Flies from Septic Tanks.—A smaller invasion of flies at one of the Embarkation Hospital wards noted above was traced to a near-by septic tank which was covered with a wood superstructure. Workmen in making certain changes had left two or three circular openings about six or seven inches in diameter. Numerous flies were coming and going through these apertures, and examination of the top sludge revealed countless maggots and pupæ on the surface where there was less moisture. Closing these apertures and spraying the contents as a matter of precaution in spots only where the larvæ and pupæ occurred soon ended the trouble. An examination of other septic tanks in other camps showed similar conditions where poor construction of the wood superstructures left crevices which provided a means of entrance and exit to flies.

The Sanitary Privy.—In the absence of modern plumbing in the country home, particular attention should be paid to the location and construction of a box privy with receptacle, or dug pit. No doubt much typhoid fever, diarrhea, dysentery, and hookworm disease is traceable to insanitary privies. Two important matters are involved; namely, first, location so as to avert pollution of wells or other water supply, and, second, construction so as to prevent flies from gaining access to the excreta, and to insure privacy.

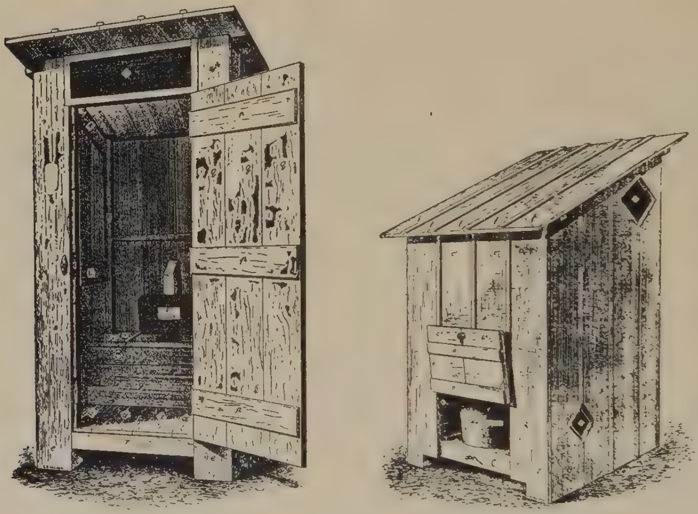


FIG. 132.—A sanitary privy,—front view to left; rear and side view to right. (After Stiles and Lumsden.)

Soil pollution is extremely dangerous, hence a clean, accessible privy is essential—accessibility is important so as to avoid the danger of delay in responding to the daily calls of nature.

A sanitary privy (Fig. 132) must meet the following requirements, according to the U. S. Department of Agriculture (Farmers' Bulletin 463—Stiles and Lumsden):

"(1) The excreta must not touch the ground; hence some kind of water-tight receptacle (box, pail, tub, barrel, tank or vault) for the excreta must be used under the seat. (2) Domesticated animals must not have access to the night soil; therefore the privy should have a trapdoor in the back to exclude them. (3) Flies and other insects must not have access to the excreta; therefore the entire privy must be made rigidly flyproof, or some substance must be used in the receptacle to protect the contents from insects."

Where the excreta is deposited in a pit or cesspool great care must be exercised in banking up around the outside of the building so as to prevent flies from gaining access to the pit. Furthermore, it may become necessary to apply quantities of chlorid of lime, crude oil, kerosene, or borax to the excreta at least twice a week during fly time.

If the privy is built on skids or can be otherwise easily moved, in addition to the treatment mentioned above, the accumulated excreta should be burned from time to time by adding straw and crude oil and setting it aflame. If sufficient water is available the country home should be provided with modern sanitary plumbing and a septic tank should be installed to receive the sewage.

Flytraps.—Unless flytraps are used to capture the flies as they emerge from their breeding places, as already described, such measures are ordinarily only excuses for failing to observe the more important cleaning-up process; the entrapped flies have ordinarily already had ample opportunity to carry filth and germs and deposit their eggs. However, traps may be useful adjuncts to other more permanent corrective measures—the more flies captured and swatted, the better, but the trapping and swatting should begin early in the spring in order to capture the early flies which are responsible for the later multiplied millions of the same species.

Furthermore, flytraps may be attached to garbage cans (Fig. 130), manure bins, etc., as already described so as to capture flies as they emerge from their breeding places. In the first case the traps must be properly baited, while in the second case the flies simply enter the traps going from the dark bin or can to the aperture over which the trap is placed, i.e., flies go toward the light.

Many different styles of flytraps are on the market and home-made traps are easily made; the principal factor is the bait—no trap will work unless it is properly baited.

It has been found that one of the most effective baits for house flies is made of blackstrap molasses, one part, mixed with three parts of water, allowed to stand for two or three days. Another attractive bait is made of a mixture of bran, mashed potatoes, sugar, yeast and water, or simply bran mash made quite thin with sour milk and sweetened with brown sugar. Stale beer, a mixture of sugar and vinegar and water, blood tankage, fish scraps, juice of crabs, etc., all have value as bait. Bait should be placed in *large* shallow pans and should be frequently renewed.

Fly Poisons.—There are many kinds of fly poisons in use, notably the proprietary cobalt and arsenical solutions. There is considerable danger in the use of many of these, as numerous newspaper accounts reporting deaths of children traceable to drinking fly poisons will testify. A very good substitute for such poisons is to be found in *formaldehyd* (formalin). This chemical may be purchased commercially in a 38 to 40 per cent solution and must be greatly diluted for use as a fly poison. The commercial 38 to 40 per cent solution is poisonous like wood alcohol, if taken internally, hence must be treated accordingly. However, when diluted to a strength of 1½ to 2 per cent ready for use it is comparatively safe. For household use two or three teaspoonfuls of the concentrated (38 to 40 per cent) formaldehyd is used to a pint of a mixture of water and milk in about equal proportions (canned milk is excellent and much less is necessary), with a small quantity of sugar or molasses added to sweeten. On a larger scale the quantities are as follows: formaldehyd, 1 pint; canned milk, 1 pint; sugar, 1 pound; water, 3 gallons.

The preparation is used as follows: place a small piece of bread (or even a small sponge) in a shallow vessel, such as a saucer or tin plate, and pour over it enough of the mixture to saturate the bread and leave some of the liquid about in the plate. Then place the receptacle where there are most flies. Flies which drink the solution are killed in the course of a few minutes and will be found scattered about nearby. The liquid must be replenished frequently.

Sodium salicylate at the rate of three tablespoonfuls of the pure chemical (a powder) to a pint of water, may be used in the same manner as the formaldehyd solution with similarly good results.

Sticky fly papers may be more of a nuisance than anything else but if properly handled serve a good purpose. A good plan is to prepare a fly paper board, viz.: take a ½-inch to ⅞-inch board 10 by 14 inches long and nail a strip of 2-inch light board along the 14-inch edge so that it extends for a short distance on either side, producing an inverted letter T viewed from the end. One-half inch from the upper edge of the board and near each end bore a hole so as to suspend it by strings passed through the holes. Tack sheets of sticky fly paper on both sides of the board, so that the drippings will fall upon the lower board.

Sticky fly paper may be made as follows according to the Kansas State Board of Health: "Take two pounds of rosin and one pint of castor oil; heat together until it looks like molasses. Take an ordinary paint brush and smear while hot on any kind of paper; an old newspaper is good."

Other Precautions.—It is highly important that rooms occupied by persons ill with certain infectious diseases be well screened. For the protection of the outside world any flies that chance to find their way inside even after the best precautions have been exercised should be killed to prevent possible escape. Typhoid excreta should never be accessible to flies and disinfection of the same by means of boiling or chemical disinfectants should be carried out before leaving the room of the patient.

Pus rags, sputum cloths, sputum cups, old bandages, etc., should not be carelessly thrown into the open garbage barrel where flies freely congregate. It may seem unnecessary to even mention these simple sanitary precautions, but gross neglect and carelessness frequently creep in where better judgment should have prevailed.

Ordinances Aimed at Fly Control.—Under city, town, or village conditions the crusade against the fly must also be made a matter of ordinance. One stable owner who does not believe in the "notion" that flies originate in horse manure (and there are many of that kind) can easily supply flies for several adjacent city blocks, hence there must be some ordinance to compel action.

Ordinances must be practical, making it possible to comply therewith; they must be constitutional and must provide a basis for conviction, i.e., our newer manure ordinances will point out that the presence of fly larvæ and pupæ is sufficient evidence that the provisions of the ordinance have not been complied with.

Stable ordinances should regulate the erection and maintenance of stables while manure ordinances should regulate the disposal of manure, and, as has already been explained, flies are gross food contaminators, hence food ordinances must also provide for protection against these and other insects as well. It is, however, manifestly unfair to compel merchants to protect their wares against flies if stable owners who are responsible for the propagation of the flies are not compelled to do their part in the prevention of the same.

Information—Application—Legislation.—Three important factors are involved in the process of house fly management, viz.: (1) Information; an informed public is essential to an efficient health movement of any kind if the results are to be of lasting benefit. (2) Application; involving the actual doing of things, simplified and made effective through information. (3) Legislation; or the creation of ordinances which can be enforced, and then enforcing them without fear or favor. Let the ordinance strike at the root of the evil. If manure, garbage, kitchen refuse, etc., are responsible for flies, then proper sanitary control should be exercised.

Natural Enemies.—The most important natural enemy of the house fly is the fly fungus, *Empusa muscæ,* first described by DeGeer in 1872 (Howard) and rediscovered annually by enthusiastic human enemies of the house fly. During late summer and autumn and throughout the moist winter in California, dead flies are frequently found clinging to curtains and walls; the abdomen is usually greatly distended, showing distinct bands due to the appearance of the intersegmental tissue brought to view by the pressing apart of the darker segmental rings. The disease is commonly known as fly cholera.

This fly fungus originates from spores which, when a fly is attacked, produce hyphæ, thread-like processes which enter the body of the fly and develop a mesh work of threads, producing great distension of the fly's abdomen. This mycelium later evidently sends out hyphæ through the intersegmental tissue, which hyphæ then produce spores or conidia. The spores are then separated often with some force, and may produce a sort of "halo" about the now dead fly. Other flies thus become easily infected. The writer has lost experimental colonies of flies in great numbers in this way in less than two weeks after the appearance of the disease.

Another very common parasite of the fly is a red mite, *Acarus muscarum.* Often several of these mites may be seen as tiny red specks on the head, neck or thorax of the house fly. Occasionally they actually retard the fly in its flight.

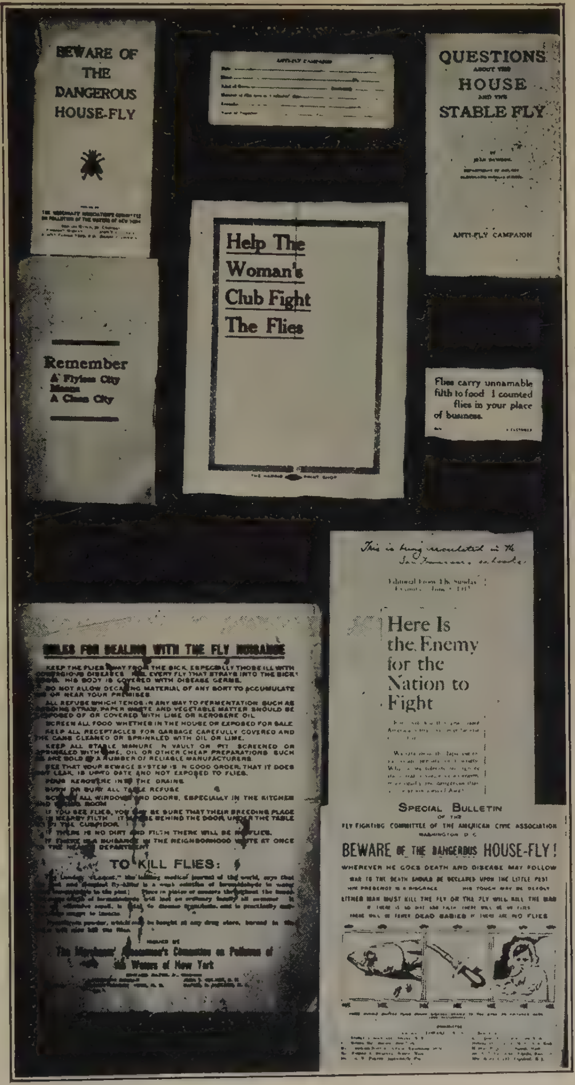
When rearing house flies from pupæ collected out of doors one is frequently surprised to find that 50 per cent or more give rise to a tiny dark metallic wasp which creeps out of the pupa case through a minute hole. These are chalcidoid wasps, one species of which is known as *Nasonia brevicornis.*

While house flies are also attacked by various other natural enemies, such as spiders, robber flies, toads, lizards, etc., their generation does not seem to be greatly affected, and man must depend more and more on suppressing the breeding places of the pernicious pest or suffer the consequences.

The Community Fly Crusade.—Under city or town conditions the crusade against the fly must be backed up by the intelligent interest of the citizens. Through intelligent coöperation it should be possible to reduce the fly population of any city or town by 95 per cent during the course of a single summer, and if action is taken in the autumn to eliminate breeding places and destroy overwintering flies, the following summer could be made practically flyless.

Numerous crusades against the house fly have been conducted in many cities in the United States with good results. In each case the work has usually been begun by an organization, already in existence, such as a Women's Club, Civic Club, Chamber of Commerce and occasionally a Board of Health. Methods of procedure are usually outlined by competent medical entomologists, parasitologists, medical officers or other individuals.

To carry out the suggested permanent preventive measures, etc., a community should, to begin with, have an appointed staff of trained inspectors, the number varying with the size of the community; four capable men working in pairs can cover considerable territory very well. No community should be without regular, trained sanitary inspectors under the direction of the Board of Health. The position of sanitary inspector should carry with it some dignity, and should be filled by men instructed in practical hygiene, including a fair knowledge of medical entomology, owing to the importance of insects in their relation to disease transmission.



BEWARE OF THE DANGEROUS HOUSE-FLY

ANTI-FLY CAMPAIGN

QUESTIONS ABOUT THE HOUSE AND THE STABLE FLY

ANTI-FLY CAMPAIGN

Help The Woman's Club Fight The Flies

Remember A Flyless City Means A Clean City

Flies carry unnamable filth to food. I counted flies in your place of business.

This is being circulated in the San Francisco schools.

Here Is the Enemy for the Nation to Fight

RULES FOR DEALING WITH THE FLY NUISANCE

KEEP THE FLIES AWAY FROM THE SICK, ESPECIALLY THOSE ILL WITH CONTAGIOUS DISEASES. KILL EVERY FLY THAT STRAYS INTO THE SICK ROOM. HIS BODY IS COVERED WITH DISEASE GERMS.

DO NOT ALLOW DECAYING MATERIAL OF ANY SORT TO ACCUMULATE ON OR NEAR YOUR PREMISES.

ALL REFUSE WHICH TENDS IN ANY WAY TO FERMENTATION, SUCH AS BEDDING STRAW, PAPER WASTE AND VEGETABLE MATTER, SHOULD BE DISPOSED OF OR COVERED WITH LIME OR KEROSENE OIL.

SCREEN ALL FOOD WHETHER IN THE HOUSE OR EXPOSED FOR SALE.

KEEP ALL RECEPTACLES FOR GARBAGE CAREFULLY COVERED AND THE CANS CLEANED OR SPRINKLED WITH OIL OR LIME.

KEEP ALL STABLE MANURE IN VAULT OR PIT, SCREENED OR SPRINKLED WITH LIME, OIL OR OTHER CHEAP PREPARATIONS SUCH AS ARE SOLD BY A NUMBER OF RELIABLE MANUFACTURERS.

SEE THAT YOUR SEWAGE SYSTEM IS IN GOOD ORDER; THAT IT DOES NOT LEAK, IS UP TO DATE AND NOT EXPOSED TO FLIES.

POUR KEROSENE INTO THE DRAINS.

BURN OR BURY ALL TABLE REFUSE.

SCREEN ALL WINDOWS AND DOORS, ESPECIALLY IN THE KITCHEN AND DINING ROOM.

IF YOU SEE FLIES, YOU MAY BE SURE THAT THEIR BREEDING PLACE IS IN NEARBY FILTH. IT MAY BE BEHIND THE DOOR, UNDER THE TABLE OR THE CUSPIDOR.

IF THERE IS NO DIRT AND FILTH THERE WILL BE NO FLIES.

IF THERE IS A NUISANCE IN THE NEIGHBORHOOD WRITE AT ONCE TO THE HEALTH DEPARTMENT.

TO KILL FLIES:

The Merchants' Association's Committee on Pollution of the Waters of New York

SPECIAL BULLETIN
OF THE
FLY FIGHTING COMMITTEE OF THE AMERICAN CIVIC ASSOCIATION
WASHINGTON D. C.

BEWARE OF THE DANGEROUS HOUSE-FLY!

WHEREVER HE GOES DEATH AND DISEASE MAY FOLLOW
WAR TO THE DEATH SHOULD BE DECLARED UPON THE LITTLE PEST
HIS PRESENCE IS A DISGRACE HIS TOUCH MAY BE DEADLY
EITHER MAN MUST KILL THE FLY OR THE FLY WILL KILL THE MAN
IF THERE IS NO DIRT AND FILTH THERE WILL BE NO FLIES
THERE WILL BE FEWER DEAD BABIES IF THERE ARE NO FLIES

FIG. 133.—Literature, bulletins, etc., used by various communities in their crusades against the house fly.

The best results will always be secured when the work is done through the Board of Health with as many civic organizations, schools, clubs, etc., as possible in intelligent and systematic coöperation to spread the propaganda. The active assistance of the school children may well be enlisted for the sake of the lesson in community service. However, little can be said in favor of offering prizes for a given quantity of flies. Let the children be taught where flies originate, their habits, etc., and then let the children report the presence of flies, say by counts, in certain situations, stores, homes, etc., and locate and report breeding places particularly. There will

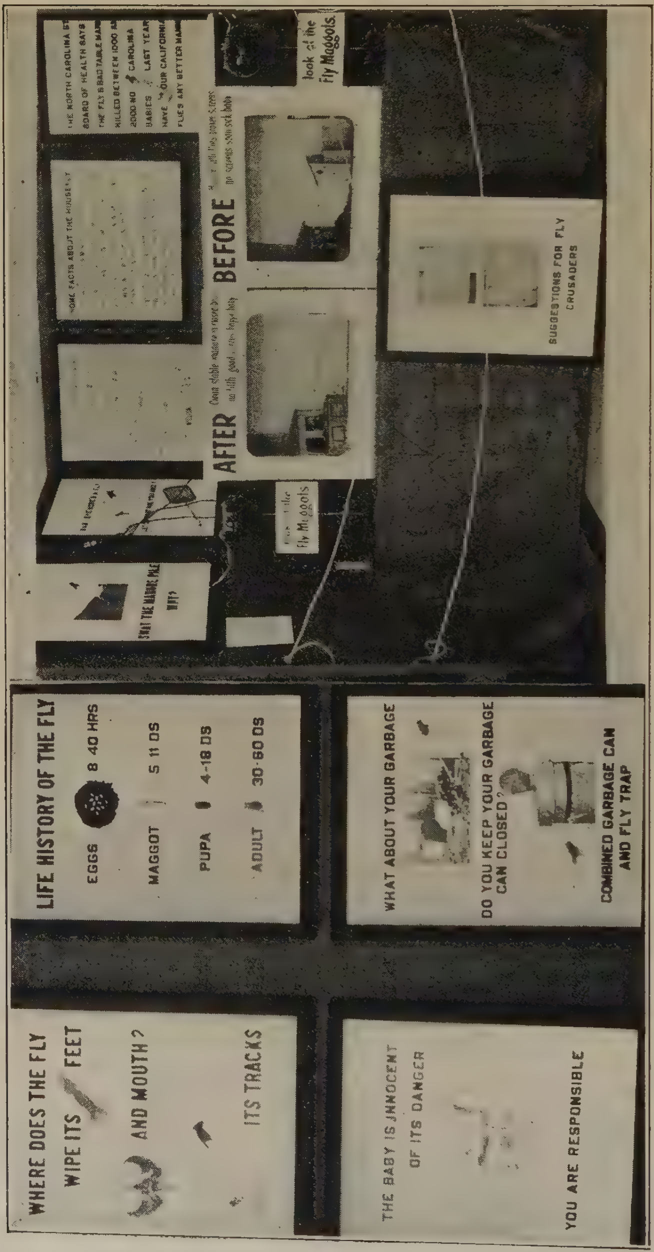

WHERE DOES THE FLY WIPE ITS FEET AND MOUTH?
ITS TRACKS
THE BABY IS INNOCENT OF ITS DANGER
YOU ARE RESPONSIBLE
LIFE HISTORY OF THE FLY
EGGS 8 40 HRS
MAGGOT 5 11 DS
PUPA 4-18 DS
ADULT 30-60 DS
WHAT ABOUT YOUR GARBAGE
DO YOU KEEP YOUR GARBAGE CAN CLOSED?
COMBINED GARBAGE CAN AND FLY TRAP
AFTER
BEFORE
SUGGESTIONS FOR FLY CRUSADERS
look at the Fly Maggots
Fly Maggots
SOME FACTS ABOUT THE HOUSEFLY
SWAT THE MANURE PILE
THE NORTH CAROLINA STATE BOARD OF HEALTH SAYS THE FLY IS BAD TABLE MANNERS KILLED BETWEEN 1000 AND 2000 NO CAROLINA BABIES LAST YEAR HAVE OUR CALIFORNIA FLIES ANY BETTER MANNERS

FIG. 134.—Showing a part of the "Fly Exhibit" at the Baby Saving Show held in Oakland, California.

be just as much interest and enthusiasm, the ultimate results will be better and the opportunity to *deal with flies* is not a factor,—the children are dealing in terms of cleanliness, hygiene and sanitation.

"Fly swatting" only serves to attract the attention away from the real issue, namely, the control of breeding places. However, a wise, properly guided agitation in this direction in the winter and spring would serve to reduce the early crop of flies materially, and the interest thus secured could gradually be won over to the side of civic cleanliness and the slogan will have changed from "swat the fly" to "swat the manure pile."

Communities in which a campaign against the house fly has been undertaken with a determination to win have shown that this insect can be controlled, and this without great labor and expense. The problem is simpler than many are willing to admit. Hearty coöperation is essential. Everybody is concerned, and everybody will share in the victory and share in the saving of financial and vital losses. Remember this,—*the presence of many flies always denotes a dirty environment.*

Figure 133 illustrates the type of literature used by various communities in their crusade against the fly, and Fig. 134 shows a part of the "House-fly Exhibit" at the Baby Saving Show held in Oakland, California, in 1914.

CHAPTER XV

BLOOD-SUCKING MUSCIDS

(Tsetse Flies, Stable Flies, Horn Flies)

A. TSETSE FLIES

Family Muscidæ, Genus Glossina

General Characteristics.—The tsetse flies belong to the Family Muscidæ, genus *Glossina,* which includes medium-sized to large flies,—from the size of a house fly to that of a blow fly. They are brownish black in color; the body is distinctly wasplike, i.e., with constricted waist (Fig. 135). The wings when at rest are closed scissors-like (not unlike the Texas screw worm fly) and project beyond the abdomen. The wing venation (Fig. 136) is characteristic "especially in the course of the fourth longitudinal vein. The anterior transverse vein is very oblique. The bend in the course of the fourth vein, before it meets the anterior transverse vein, is absolutely diagnostic" (Stephens and Christophers). The palpi are nearly as long as the proboscis, which points bayonet-like in front of the head. The antennal arista is plumose only on the upper side (Fig. 137). The mouth parts consist of the labium which ensheaths the two piercing

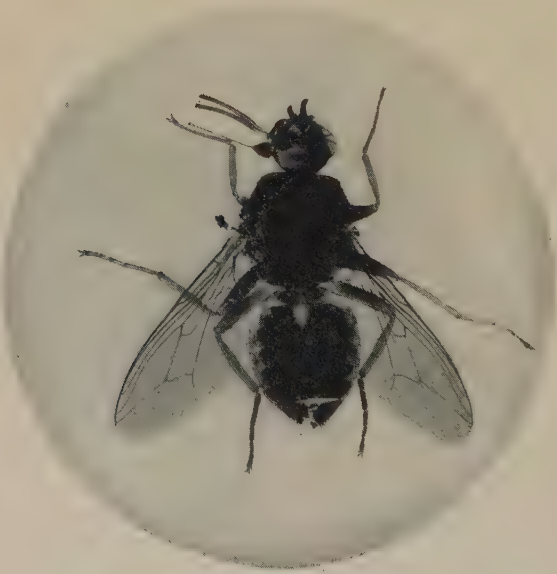


FIG. 135.—*Glossina palpalis* (tsetse fly), carrier of African sleeping sickness. × 3.6.

setæ,—the dorsally located labrum and the inner hypopharynx, as in Stomoxys. The characteristic "onion-shaped" bulb is conspicuously located at the base of the proboscis (Fig. 138).

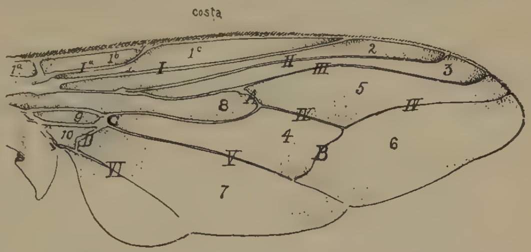


FIG. 136.—Wing of a Glossina fly. Ia, auxiliary vein; I to VI = first to sixth longitudinal veins; *A*, anterior transverse vein; *B*, posterior transverse vein; *C*, anterior basal transverse vein; *D*, posterior basal transverse vein; 1*a*, 1*b*, 1*c*, first, second and third costal cells; 2, marginal cell; 3, submarginal cell; 4, discal cell; 5, 6, 7, first, second and third posterior cells; 8, anterior basal cell; 9, posterior basal cell; 10, anal cell. (Nomenclature after Austen.) × 8.

Distribution and Habits.— The tsetse flies are restricted to certain parts of Africa, known as "fly-belts." A portion of southwestern Arabia is also said to be inhabited by these flies. They occur most abundantly along heavily wooded water courses, where big game animals abound, and apparently avoid unshaded plains, direct sunlight being detrimental to the insects, particularly *Glossina palpalis* Rob. Desv., although *Glossina tachinoides* Westw. favors more open country. It is of interest to know that according to Swynnerton[1] certain species such as particularly *Glossina pallidipes* Austen and to a lesser degree *G. morsitans* Westw. are wild-mammal flies, and others such as particularly *G. swynnertoni* and *G. palpalis* are "man" flies and that consequently with the reduction of wild animals, such as the antelope, man would become the chief "blood supplier" particularly under concentrated conditions in bush villages.

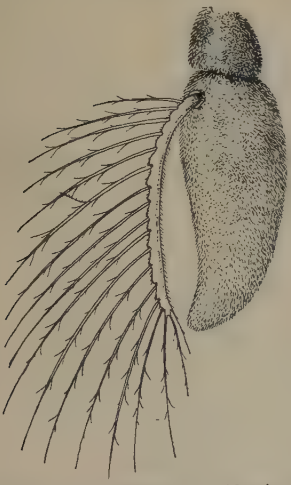


FIG. 137.—Antenna of a Glossina fly, showing arista with branched hairs. (Much enlarged.)

The tsetses are typical intermittent blood-sucking insects, both warm-blooded and cold-blooded animals being attacked. Both sexes partake of this habit. Although they are typically day-flying insects, biting mainly during the brighter part of the day, they are also known to bite at night. They apparently prefer dark objects to white ones, and attack negoes much more readily than white persons. White clothing consequently affords some protection against their attacks.

Life History.—The female tsetse fly gives birth to full grown larvæ, extruded one at a time at intervals of 9 to 10 days during the lifetime of the insect. The whitish larvæ burrow lightly into the ground and pupate within an hour or two. The pupæ rapidly darken and soon take the form shown in Fig. 139. The pupal stage requires from 3 to 7 or 8 weeks, depending on the temperature. Hindle states that for *G. palpalis* from 32 to 33 days are required at a temperature of 25° to 27° C.

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[1] Swynnerton, C. F. M., 1923. The entomological aspects of an outbreak of sleeping sickness near Mwanza, Tanganyika Territory. Bull. Ento. Res., Vol. XIII, Part 3, pp. 317-370.

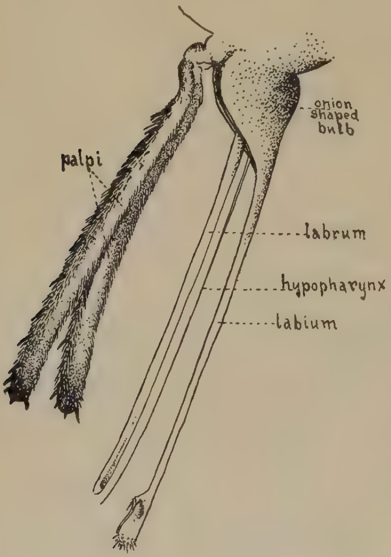

Fig. 138.—Mouth parts of a Glossina fly. × 17.

The flies are said to have a striking dislike for excrementous matter, and the larvæ are ordinarily deposited in the root tangles of the banana, mangroves and other tropical vegetation where the soil is dry and loose.

Trypanosomiasis.—The tsetse flies are important carriers of the Trypanosoma of warm-blooded animals. The term *Trypanosomiasis* applies to all diseases produced by flagellate Protozoan parasites of the genus Trypanosoma, and includes such diseases as African sleeping sickness, nagana, surra, etc. The trypanosomes belong to the Class Zoömastigophora and to the Order Trypanosomatida, are microscopic, elongate, more or less spindle-shaped, blood, lymph or cerebrospinal fluid inhabiting parasites, found in many species of vertebrate animals, from fish to man, and appar-

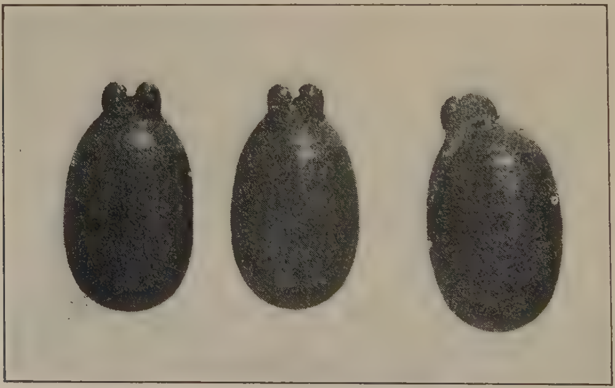

Fig. 139.—Pupæ of the Glossina fly. × 4.8.

ently not all species are pathogenic. At or near the middle of these spindle-shaped organisms lies an oval or round body, the *nucleus;* anterior to this is usually the rather long filamentous appendage, the *flagellum,* which can be traced back along the border of a flaplike structure, or *undulating membrane,* to a body considerably smaller than the nucleus, lying in the posterior end, the *blepharoplast* (Fig. 1). Immediately adjacent to this blepharoplast there is often a vacuole, and distributed throughout the body of the trypanosome are distinct chromatin bodies or points.

The Trypanosoma increase in the vertebrate host by longitudinal division. Both the nucleus and the blepharoplast divide, and the flagellum splits into two, or in some species a new flagellum originates from the new blepharoplast. Thus, in the latter case, the flagellum is first located posteriorly and migrates anteriorly as the organism grows older. In *Trypanosoma lewisi* there may be found a rosette. The developmental stages which are undergone in the intermediary hosts are not well known, but certainly a series of changes transpires within the insect host.

There are also described male forms said to be "excessively slender, staining deep blue, with a sharply defined, rather long, chromatin-rich nucleus; more actively motile than other forms: also female forms with short flagellum membrane, little folded, two or three times as broad as other forms; staining a light blue; have few or no granules, and the nucleus is spherical" (Stephens and Christophers). Besides these there are also described indifferent forms, "the most numerous form, nucleus not sharply defined and the protoplasm containing numerous granules"; also encysted forms, latent forms and involution forms.

The first trypanosome was discovered by Valentin in 1841 in the blood of the salmon. The name *Trypanosoma* [1] was given to these organisms by Gruby in 1842-43. The attention was not called to trypanosomes of mammals until the work of Lewis in 1878, on the parasites of the blood of the rat in India. After that followed the discovery of other important *pathogenic* trypanosomes, e.g., in 1880 Evans discovered the trypanosome causing surra in horses; in 1897 Bruce found the trypanosome of nagana, known as the tsetse-fly disease. In 1901 Dutton found trypanosomes in human blood, and in 1903 Castellani found them in the cerebrospinal fluid of negroes in Uganda suffering from sleeping sickness. The trypanosomes found by Castellani were supposed to be a different species from that of Dutton (*Trypanosoma gambiense*) and were called *T. ugandense* Castellani, 1903. Kruse later gave to this trypanosome the name *T. castellanii* Kruse. The important discoveries of Dutton and Castellani were confirmed by D. Bruce, who found these trypanosomes 38 times out of 38 in the cerebrospinal fluid obtained by a lumbar puncture in natives of Uganda suffering from sleeping sickness, and 12 times out of 13 in the blood. According to the rules of priority applied to nomenclature, the last two specific names must give way to *Trypanosoma gambiense* Dutton, the older term. A second species of trypanosome producing sleeping sickness in Rhodesia, Nyasaland, and adjoining territory was described in 1913 by Stephens and Fantham (*loc. cit.*) as *T. rhodesiense.*

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[1] Laveran, A., et Mesnil, 1904. Trypanosomes et Trypanosomiasis, Paris. xi + 417 pp.

African Sleeping Sickness.—The two types of sleeping sickness already mentioned, namely the Gambian and the Rhodesian, are very similar in their symptomatology, although the latter is regarded as more virulent and runs a more rapid course. It is of interest to note that Castellani and Chalmers (Manual of Tropical Medicine) recognize three types of the disease and substitute the generic term *Castellanella* for *Trypanosoma,* thus: (1) the Equatorial type caused by *Castellanella castellanii* (Kruse) Chalmers, and spread by *Glossina palpalis;* (2) the Southern type caused by *Castellanella rhodesiensis* (Stephens and Fantham) Chalmers, and spread by *Glossina morsitans;* and (3) the Northwestern type, caused by *Castellanella gambiensis* (Dutton) Chalmers, "spread by some as yet not clearly differentiated tsetse fly, which may or may not be *Glossina palpalis,* and which Dutton suggested might possibly be *Glossina tachinoides.*"

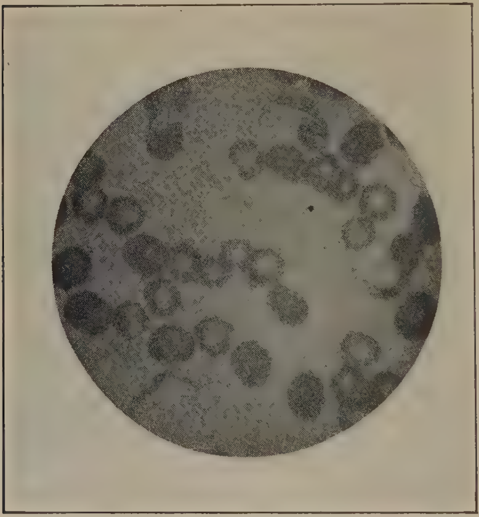
FIG. 140.—Photomicrograph of a blood smear, showing *Trypanosoma gambiense* of African sleeping sickness. × 625.

The disease is widely distributed in Africa, extending along the west coast from Senegal (in part) to Angola (in part) and eastward to the Valley of the upper Nile. It has been estimated that between 1896 and 1906 from 400,000 to 500,000 natives perished from this pestilence. Dutton and Todd found that in some villages from 30 per cent to 50 per cent of the population was infected.

Age does not affect the distribution of the malady, since children, as young as eighteen months to two years, have been known to be infected. Sex does not influence the disease. Occupation and social position, however, do show a marked influence. The great majority of the cases observed are among the agricultural and lower classes.

The seasons seem not to influence the advance of the disease, or perhaps rather because of the relatively long period of incubation or of seeming latency which precedes the usual appearance of nervous symptoms, the influence of the seasons is hard to determine.

There are two distinct phases in sleeping sickness after the incubation period which varies from about two weeks to several months or even years. During the first phase the trypanosomes are in the blood (Fig. 140), usually in small numbers. With the negroes there are said to be no morbid symptoms, but with the whites it is manifested by an irregular fever. Glandular enlargement is an early and constant feature, and the trypanosomes are practically always found in the enlarged glands. In the second phase, the trypanosomes are constantly found in the cerebrospinal fluid; there is nervousness and trembling until drowsiness appears, the fever taking on the hectic character. Drowsiness gives way to lethargy, and finally the victim falls into a comatose state.

Transmission.—The natives of French Guinea long attributed the power of disseminating sleeping sickness to flies and it had already been shown that nagana, a disease of horses and dogs, was transmitted by tsetse flies when Dutton and Todd studied the biting flies of Gambiense. These investigators found that of the flies which bite man and animals, *Tabanus dorsovittata* and *Glossina palpalis* were the most important, the latter being very common in western Africa, where it abounds in the mangroves which line the rivers and water banks during the warmer months when these insects are very troublesome. Experiments, however, made by these workers gave negative results. It was Bruce and his collaborators who subsequently went over the matter and showed that *Glossina palpalis* is the principal agent of transmission.

Animal experimentation indicates that these flies can transmit the causative protozoon mechanically for a period of less than 48 hours, though the organisms become more and more attenuated after the fly has bitten the diseased individual and loses its power of infection in less than 48 hours. Thus the tsetse fly proves itself a mechanical carrier for only a few hours during which time its soiled proboscis is involved, i.e., trypanosomes are injected into the wound produced by the bite before the proboscis is cleaned.

It is, however, well known that trypanosomes taken into the stomach of the fly pass through a metamorphosis, developing into two forms known as male and female. These latter give way to an indifferent type and in from 4 to 5 days all trypanosomes disappear. Recent experimental evidence indicates that the flies become infective once more at the end of about 4 weeks, and then appear in the salivary glands of the insects. Nuttall[1] states that the trypanosomes appear in the salivary glands of the fly after a period of 25 to 28 days following the infective meal. During this interval, except as noted above, the flies are incapable of producing infection. The parasites in the salivary glands of the fly resemble *T. gambiense* as seen in the mammalian blood and they persist as long as the fly lives. The Sleeping Sickness Commission has found that infectivity lasts at least ninety-six days. The life of a female *Gl. palpalis* in captivity has been observed to be about four and one half months. The same author (Nuttall) states that injections of *either* the *gut content* or *salivary gland emulsion* produce infection after about the 25th day. Under laboratory conditions only about 5 per cent or 6 per cent of the flies become infective.

Nagana.—As sleeping sickness is to man so is nagana to domesticated animals. *Trypanosoma brucei* Plimm and Brad. is the causative organism of nagana, which malady was early known as the fatal tsetse-fly disease of African horses and mules, less fatal in cattle and sheep. The disease is characterized by progressive emaciation, fever, edema of the abdomen and genitalia and marked depression. The trypanosomes are found in the blood and especially the lymph-gland swellings from the beginning of the first symptoms.

For some years nagana was known as *the* tsetse-fly disease. *Glossina morsitans* and *Gl. longipalpus* relate to its transmission in practically the same way that *Glossina palpalis* does to sleeping sickness, i.e., the fly is infective for three or four days after feeding on an infected animal, then becomes non-infective for a period of about 3 weeks and then again becomes infective, remaining so for the rest of its life. The incubation period after inoculation into the body of the host is said to be about 10 days.

Control of the Tsetse Fly.—Thus far relatively little progress has been made in the treatment or immunology of tsetse-fly diseases; upon the latter no doubt rests the ultimate solution of the problem. A ready means for the destruction of the flies is unknown. Although numerous flies may be destroyed by catching them with sticky substances such as bird lime, their reduction is hardly if at all noticeable. Repellents, though many have been tried, give poor results. The general and practical control of breeding places offers insurmountable difficulties owing to the fact that the larvæ are retained within the body of the female, hence are not directly dependent upon an external food supply. Starving the adult flies by eliminating wild animals upon which they may be dependent for blood can hardly be accomplished, for deprived of this source of blood, the flies would turn to man himself in even greater numbers and with greater danger. In order to prevent the regrowth of once cleared areas and the reintroduction of the tsetse, Swynnerton (*loc. cit.*) suggests the use of domesticated elands. He writes, "The presence of a herd of domesticated elands at a village would probably be the greatest safeguard against sleeping sickness."

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[1] Nuttall, G. H. F. The Herter Lectures: II, Trypanosomiasis, Parasitology, Vol. V, No. 4, pp 275-288.

A study of the habits of the tsetse shows that villages located in the midst of extensive clearings and not too near water courses are largely free from these insects. The clearings should be from 400 to 600 yards in width and can best be maintained by placing them under cultivation (rice and larger shade-producing vegetation excepted). Wells should be utilized for water supply.

Screening is an important adjunct to the control of sleeping sickness. Dwellings, trains, steamers and other conveyances should be carefully screened.

The use of veils, gloves and loose white garments is highly recommended.

Since the tsetse-fly disease spreads along trade routes and extends from infected centers, there is an obvious demand for the control of transportation to prevent as far as possible the employ of infected individuals.

Owing to the complicated colonial situation in Africa, both geographically and commercially, the control of trypanosomiasis calls for hearty coöperation among the powers concerned.

Systematic.—All flies belonging to the genus Glossina partake of the following characteristics: medium-sized flies from size of house fly to blowfly, dark brownish in color; wings when at rest folded scissors-like over the back, longer than the abdomen; fourth longitudinal vein bends sharply before meeting the anterior transverse vein; proboscis when at rest projecting horizontally in front of the head; the base of proboscis is provided with an onion-shaped bulbous expansion; the arista is plumed on upper side.

The following species[1] may be mentioned:

(1) *Glossina palpalis* Robineau-Desvoidy is a medium-sized tsetse fly from 8 to 9 mm. in length. Its general color is light brown with a dusting of gray. The antennæ are dusky, the arista has 18 aristal hairs. The thorax heavily dusted with gray and has dark lines and spots. The abdomen is light brown beneath dusted with gray; above it is nearly black with a longitudinal, median narrow light brown stripe. The halteres are white. The legs are light brown with indistinct dark spots on the tarsi. The hind tarsi are black.

This species is found throughout West Africa from the Congo to the Senegal, wherever there is water.

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[1] Grünberg, Karl, 1907. Die Blutsaugenden Dipteren. Verlag von Gustav Fischer in Jena. vi + 188 pp., 127 figures. (The above descriptions of tsetse flies are adapted after this author.)

Glossina palpalis var. *wellmani* Austin varies from the above in that it has a yellowish brown frontal stripe, and tarsi nearly white. It occurs in Angola.

Glossina morsitans Westw. is said to be almost identical with *Glossina longipalpus*, except that it is ordinarily somewhat smaller. Grünberg declares that it would be more correct to consider *morsitans* as a variety of *longipalpus*. Furthermore, because of the fact that both species are transmitters of nagana, the separation of the two species has no great practical value.

The distribution of this species coincides with that of *Gl. longipalpus*, though it is ordinarily attributed to a much greater portion of Africa, because its habitat consists of less heavily wooded and drier areas.

Glossina longipalpus Wiedem. is also a medium-sized fly ranging from 8 to 10 mm. in length. The color is light brown with very little gray. The antennæ are dark brown, the arista is light brown with 25 aristal hairs. The palpi are light brown, tipped with black. The thorax is heavily dusted with gray. The abdomen is light brown, marked dorsally, to the right and left, on the 2-6 segments with black semilunar lateral spots, resting broadly on the proximal end of each segment. The halteres are white. The legs are light brown with black tipped pro- and meso-thoracic tarsi; the hind legs are black.

This species occurs in Sierra Leone and British Central Africa.

Other species of Glossina flies are the following: *Gl. pallicera* with 20-22 aristal hairs (Grünberg); *Gl. pallidipes* with 25 aristal hairs (Grünberg); *Gl. longipennis* with 18-20 aristal hairs (Grünberg); and *Gl. fusca*, a large species (11-13 mm.) also with 18-20 aristal hairs (Grünberg).

The student of tsetse flies will find Austen and Hegh's "Tsetse Flies" (Imperial Bureau of Entomology) an indispensable aid in his work.

B. Stomoxys or Stable Flies

Family Muscidæ, Genus Stomoxys

General Characteristics.—Owing to similarity in color and size (Fig. 141) the *Stomoxys* fly is often mistaken for the common house fly, *Musca domestica*. However, the former is more robust with broader abdomen. In color it is brownish gray with a greenish yellow sheen; the outer of the four longitudinal thoracic stripes are broken and the abdomen is more or less checkered. The wings when at rest are widely spread apart at the tips, are distinctly iridescent and the apical cell is open. When resting the fly has its head thrown well up and the wings slope decidedly toward the surface upon which it has settled. The proboscis protrudes bayonet-like in front of the head. The antennal arista, unlike the house fly, bear setæ on the upper side only (Fig. 29).

Stomoxys calcitrans Linn. enjoys practically a worldwide distribution, while *Stomoxys nigra* Macq. and other species very difficult to differentiate occur only in Africa and Asia.

Habits.—Although the Stomoxys fly *Stomoxys calcitrans* Linn. is commonly called the stable fly, it occurs much less abundantly (often absent) about stables than does the house fly. "Biting house fly" is a term often applied, since the fly commonly occurs indoors especially in the autumn and during rainy weather. The Stomoxys fly is typically an out-of-door fly and is usually to be found in summer where domesticated animals occur, especially cattle. Its occurrence around stables is traceable to the presence of cattle or horses usually, and not to the presence of manures directly. Sunny fences, walls, light-colored canvas coverings and light objects in general when in the proximity of cattle are abundantly frequented by Stomoxys flies.

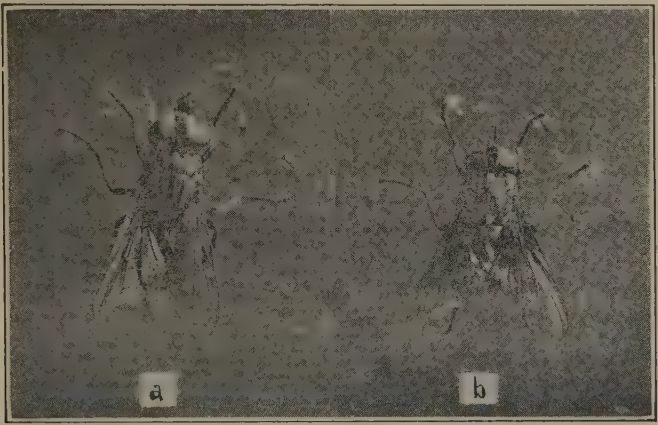

FIG. 141.—(a) The common house fly (*Musca domestica*); (*b*) the stable fly (*Stomoxys calcitrans*). × 2.5.

The Stomoxys fly is a vicious "biter," draws blood quickly and fills up to full capacity in from 3 to 4 minutes if undisturbed, but ordinarily even when undisturbed changes position frequently or flies to another animal, where the meal is continued. This fly feeds readily on many species of warm-blooded animals, for example, rats, guinea-pigs, rabbits, monkeys, cattle, horses and man. Both sexes are blood-sucking. The flight of the Stomoxys fly is direct and swift.

Light Reactions.—The Stomoxys flies respond positively and strongly to light, being much more responsive to this stimulus than house flies, hence are normally out-of-door flies. Because of the strong positive reaction to light these flies can easily be transferred from breeding jars to other receptacles by covering the former with black cloth, leaving an opening toward the light into which opening a test tube is inserted. Hundreds of flies can thus easily be transferred in a few minutes. Observations on the photic reactions of these flies bid fair to give very interesting results.

The larvæ, like those of flesh flies and house flies, are decidedly negative to light. In breeding these flies, the larvæ must be supplied with sufficient material so that they can bury themselves deeply,—they are thus protected against light, and enough moisture must be supplied to keep the mass of material in a "soggy" condition. Too much moisture is, however, destructive.

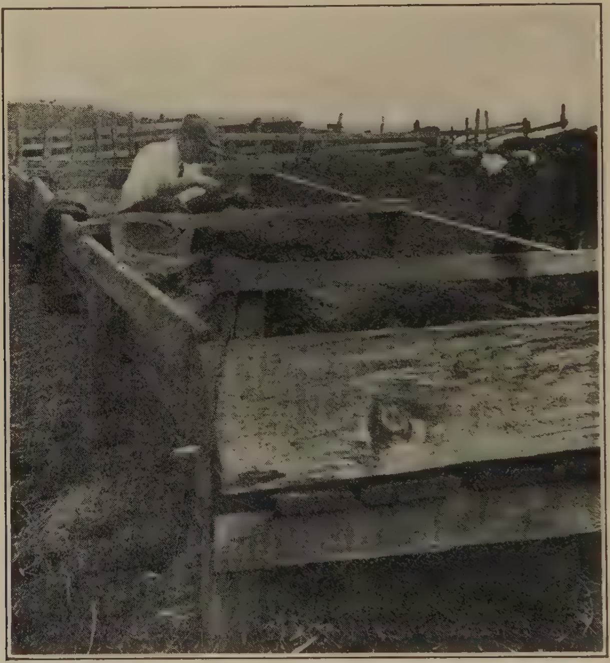

FIG. 142.—A feed trough for dairy cattle which furnishes an ideal breeding place for Stomoxys flies. The moist lower layers of material in the trough furnish abundant food for the larvæ.

Breeding Habits and Life History.—Although the Stomoxys fly can successfully be reared in the manures of horses, cattle, sheep, etc., it may be safely said that it does not breed commonly in excrement under field conditions unless straw or hay predominates. For every thousand house flies bred in horse manure, there are, as a rule, not more than one or two Stomoxys flies. The very best breeding places are afforded by the left-over hay, alfalfa or grain, in the bottoms or underneath out-of-door feed troughs in connection with dairies (Fig. 142). This material soon becomes soggy and ferments, and here practically pure cultures of Stomoxys larvæ may be procured. The material must be moist; dryness prevents development. Piles of wet fermenting weeds and lawn cuttings also furnish fairly good breeding material. Piles of decaying onions have been found by the writer to harbor myriads of larvæ late in autumn.

The larvæ of Stomoxys and of the house fly can readily be differentiated by the form, size and position of the posterior spiracles (Fig. 143), otherwise they resemble each other closely. The pair of posterior spiracles of the Stomoxys larva are roughly triangular, widely separated and situated near the periphery, while in the house fly larva they are elliptical, quite large, close together and more central in position.

The eggs of the Stomoxys fly are about 1 mm. long, curved on one side, straight and grooved on the opposite side. In depositing her eggs the female fly often crawls far into the loose material, depositing her eggs usually in little pockets in small numbers, often in pairs. Eggs deposited range in number from 23 to 102, usually between 25 and 50, and there are ordinarily four or five layings. Mitzmain[1] has found in his observations made in the Philippine Islands that the maximum number of eggs produced by a single *Stomoxys* is 632 and possibly 820, and that there may be as many as twenty depositions during the lifetime of the female.

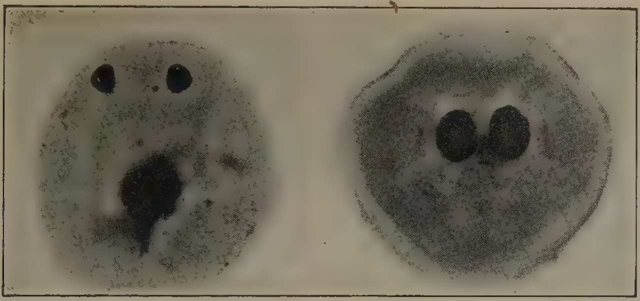

FIG. 143.—Showing posterior larval spiracles of *Stomoxys calcitrans* (left); *Musca domestica* (right). × 21.

The incubation period varies from 2 to 5 days, commonly 3 days, at a temperature of 26° C. Higher temperatures result in a shorter incubation period. The newly hatched larvæ bury themselves in their food at once, thus protecting themselves against light and dryness. At a temperature of from 21° to 26° C. the larvæ reach full growth in from 14 to 26 days. Mitzmain (*loc. cit.*) found that the larval stage averaged 12 days at a room temperature of 30° to 31° C.

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[1] Mitzmain, M. B., 1913. The bionomics of *Stomoxys calcitrans* Linnæus; a preliminary account. The Philippine Journal of Science, Vol. VIII, No. 1, Sec. B, pp. 29-48.

Before pupation the larvæ usually crawl into the drier layers of the breeding material, where the chestnut-colored pupæ are often found in enormous numbers. The pupæ are from 6 to 7 mm. long and may be recognized by the posterior spiracles as in the larva. The pupal period also varies, dependent largely on temperature. At a temperature of from 21° to 26° C. this period varies from 6 to 26 days, with the greatest frequency between 9 days and 13 days (Table XIII).

TABLE XIII

Table Showing Day of Emergence of Stomoxys Calcitrans after Day of Pupation. Larvæ Pupating in an Insectary at a Temperature of from 21° to 26° C.

	Pupal Period in Days	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Totals
A	No. flies	1	2	42	108	424	167	85	15	8	4	2	0					858
B	No. flies	3	10	12	80	200	70	20	16	10	19	4	3	0				427
C	No. flies	20	125	85	100	200	70	120	50	75	30	20	30	40	15	4	0	887

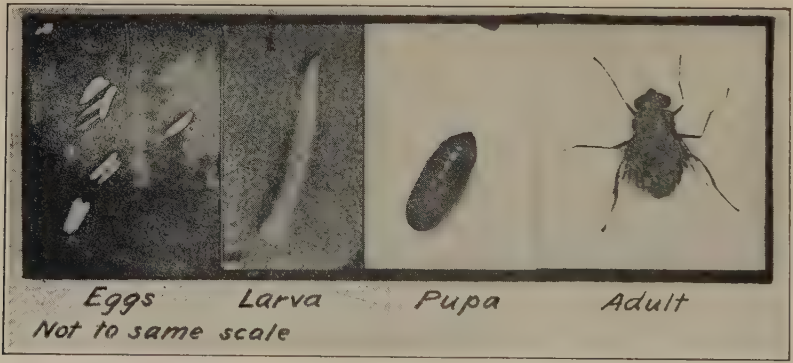

Fig. 144.—Showing the life history of the stable fly or stomoxys fly (*Stomoxys calcitrans*. (Photo by H. F. Gray.) × 2.

At an average temperature of 29° C. Mitzmain (*loc. cit.*) found the pupal period to average 5 days.

If not handicapped, the imago emerges with astonishing rapidity, crawls away, unfolds its wings and is ready to fly away in less than half an hour. The fact that the proboscis is temporarily attached beneath the thorax gives the newly emerged insect a very peculiar appearance, and it may then be easily mistaken for a house fly.

Summarizing the life history of the Stomoxys fly (Fig. 144) it may be said that at a temperature of 21° to 26° C. the *shortest* periods are: egg, 2 days; larva, 14 days; pupa, 6 days; total, 22 days; the *average*, egg, 3 days; larva, 15 days; pupa, 10 days; total, 28 days; the *maxi-*

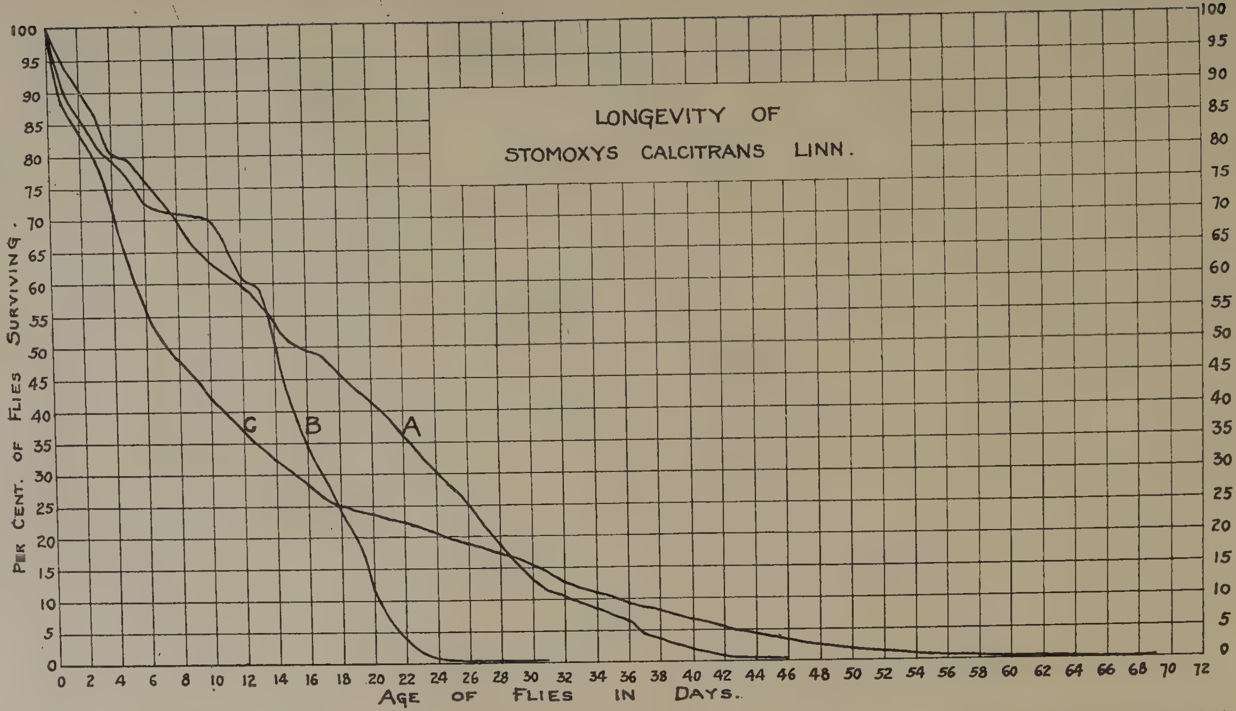

FIG. 145.—*Longevity chart of Stomoxys calcitrans: A,* percentage curve of 1,300 stable flies surviving on each day after hatching; hatched between Dec. 12 and 20, 1912; used in Experiment 1; room temperature, usually between 12° and 20° C. (53.6° and 68° F.). *B,* percentage curve of 650 stable flies surviving on each day after hatching; hatched between Dec. 22, 1912, and Jan. 3, 1913; used in Experiment 3; insectary temperature, from 23° to 36° C. (from 73.4° to 78.8° F.). *C,* percentage curve of 2,000 stable flies surviving on each day after hatching; hatched between April 7 and 18, 1913; used in Experiments 5, 6 and 7; room temperature, usually between 12° and 20° C.

mum, egg, 5 days; larva, 26 days; pupa, 26 days; total, 57 days. The total time at 21° C. from the laying of the egg to the emergence of the imagines was from 33 days to 36 days as observed in five individual cases. Mitzmain (*loc. cit.*) reports the development of this fly in 12 days under optimum conditions.

Copulation takes place within a week and egg deposition begins in about 18 days after emergence from the pupa cases at a temperature of from 21° to 26° C. Higher temperatures undoubtedly decrease this time.

Longevity.—With approximately 4,000 flies under continuous daily observation in glass quart jars, 50 flies to a set, the writer has found that the average length of life of the Stomoxys fly under favorable conditions of feeding (i.e., daily feedings on monkeys or rabbits) is about 20 days. The maximum life under these conditions was found to be 69 days and several hours,—observed in a female (Fig. 145).

Mitzmain (*loc. cit.*) has found the maximum for a female fly to be 72 days and for the male 94 days.

The writer has observed that a set of flies which fed only on sugar water deposited no eggs, although many of them lived 20 days or longer, while control flies fed on blood did lay eggs. Hence it seems apparent that the flies must have blood in order to develop eggs.

As a Cattle Pest.—In a most useful and interesting paper on the stable fly, as a live stock pest, Bishopp [1] regards this fly as very important. Injury is brought about in various ways, e.g., worry, due to the attacks of myriads of flies; loss of blood; lessening of the milk supply from 40 to 60 per cent; loss of flesh; bringing on attacks of acute Texas fever if the cattle are already parasitized; etc.

Surra.—Surra is one of the most important diseases of horses in the Philippine Islands, and its spread on these islands behooves the government to a most careful consideration of its transmission. The causative organism is *Trypanosoma evansi* which is harbored by a number of hosts, mainly horses, in which the disease is highly fatal, also mules and the carabao, and experimentally in monkeys, guinea-pigs and rabbits.

The Stomoxys fly has been regarded by some authors as an important carrier of this trypanosome. Unfortunately there is little or no conclusive experimental evidence in favor of this theory. Mitzmain [2] in a most important contribution on this subject presents very good evidence that this fly need not be regarded as a factor in the transmission of surra, that its spread is attributable mainly to a horsefly, *Tabanus striatus,* the common horsefly of the Philippine Islands. In a letter to the writer Mitzmain states that *Stomoxys calcitrans* was used daily on clean animals up to ninety-four days after removal from the infected hosts without successful transmission.

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[1] Bishopp, F. C., 1913. The stable fly (*Stomoxys calcitrans* L.), an important live stock pest. Journ. Econ. Ento., Vol. 6, No. 1, pp. 112-127.

[2] Mitzmain, M. B., 1913 (*loc. cit.*).

Poliomyelitis.—Poliomyelitis, also known as infantile paralysis, was first described in 1820 in Norway, and it seems quite likely that the spread of this disease is traceable to immigrants from the Scandinavian peninsula. Severe epidemics of this disease are apparently not recorded until recent years, the latter few years of the last century and the beginning of this.

Apparently the first epidemic to be reported in the United States was in 1894 in Vermont, and a year later a small epidemic was reported in California. During the past dozen years the disease has been spreading to an alarming extent. In 1907 over 2,500 cases occurred in New York State, in 1909 nearly 1,000 cases in Massachusetts and over 600 cases in Nebraska; in California for the year beginning November 1, 1911, and ending October 31, 1912, there were 495 cases with a mortality of 23.3 per cent. Children between the ages of three and four seem to be most susceptible to the disease and the mortality is highest between these ages. The disease is, however, not restricted to infants, since adults are known to show characteristic symptoms.

The symptoms of the disease in the first stage are vague,—there is fever, nervousness, gastric and intestinal disturbances, loss of appetite and headache; these symptoms are followed by the more definite conditions of paralysis of arms and legs, usually asymmetrical, trembling and finally complete paralysis. Death often occurs through paralysis of the diaphragmatic muscles. If recovery takes place, often months elapse before complete use of arms and legs is regained.

The causative organism is unknown, but is filterable. The incubation period in the human being has not been ascertained, but in monkeys it is as short as three or four days and in these animals death often ensues in five days.

The epidemiology of poliomyelitis is complicated. The virus is known to retain its virulence under most adverse conditions, said to remain virulent in dust (Neustaedter and Thro).[1] The disease can be produced by painting the nasal mucosa with the virus. All this would seem to point toward ease of transmission and infection, which is really not the case, otherwise epidemics of this disease in schools would be common occurrences. Again, healthy monkeys caged with monkeys infected with the disease do not readily become infected by contact. Notwithstanding these facts cases are cited in which the disease has been transmitted by contact. On the other hand cases are numerous in which the patients are far separated from other cases.

Because of this peculiar distribution the attention of investigators has been called to the possibility of insect transmission. The following quotation is taken from the California State Board of Health Special Bulletin on Poliomyelitis (October 15, 1912).

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[1] Neustaedter, M., and Thro, W. C., N. Y. Med. Journ., 1911, Vol. XCIV, p. 813.

> "In 1909, Dr. J. H. Hill, Epidemiologist of the Minnesota State Board of Health, presented the apparent relation of dusts to the occurrence of the disease and its frequent appearance on premises having accommodations for horses and other animals.
>
> "Professor W. B. Herms, of the University of California, has for several years considered the 'biting fly' (*Stomoxys calcitrans*) to be a possible factor in transmitting the disease.
>
> "Dr. M. W. Richardson, Secretary Massachusetts State Board of Health, in 1911 was one of the first workers to begin the systematic collection of insects found on the premises of poliomyelitis cases. His observations and his strong suspicion of the 'biting fly' based upon finding this species of fly as the only insect constantly present in the majority of houses where poliomyelitis had occurred, were presented to the American Public Health Association in Havana in December, 1911.
>
> "Dr. Flexner of the Rockefeller Institute for Medical Research and his associates, in their several progress reports on Poliomyelitis have pointed out the possibility of insects being a factor in disseminating the disease, and have emphasized the fact that if this could be proved it would explain many of the difficult points in its epidemiology.
>
> "Dr. Frost of the United States Public Health Service has been constantly observing the epidemiological factors in American outbreaks of poliomyelitis during the past three years, in an effort to collect evidence supporting or disproving the efficiency of administrative measures that have hitherto prevailed.
>
> "In the summer of 1912, Dr. Richardson continued his work and Dr. M. J. Rosenau of Harvard University began a series of scientific experiments to demonstrate if possible, whether poliomyelitis can be transferred from infected monkeys to well monkeys through the agency of the 'biting fly' (*Stomoxys calcitrans*). In a preliminary scientific announcement, September 26, 1912, before the International Hygienic Congress, Dr. Rosenau stated that he had succeeded in accomplishing this in his first series of experiments."

The following is quoted from a report of Rosenau's work in the Journal of the American Medical Association (Vol. LIX, No. 14, p. 1314) under "Proceedings of the International Congress on Hygiene and Demography."

> "In reference to the transmission of poliomyelitis by the biting fly, we were led to focus our attention on this biting fly (*Stomoxys calcitrans*) as an intermediate host in the transmission of a particular infection referred to by Dr. Richardson. When I first began to study the disease, I regarded it probably as one which is spread by direct contagion, by contact, either directly or indirectly, from person to person. The first circumstance which shook my faith that we were dealing with a contagious disease was the fact that we had eighteen negative results in attempting to prove the presence of the virus in the secretions from the nose and throat. I could not help asking at the time if it were not possible to find the virus, which is so potent, in the secretions of the nose and throat of persons who have the disease and those who are convalescing from the disease. These results were confirmed at the same time by Strauss, of New York,

who had negative results in a large series and by Neustaedter's recent results and by other results, all of the examinations having proven negative excepting one recently reported by Kline, Patterson and his associates at this congress and in the literature recently.

"A second circumstance which led me to believe we were not dealing with a contagious disease was the fact brought out by Dr. Richardson. Children in all stages of this disease were crowded into schools, institutions, tenement districts and other places where there was every chance for the spread of the disease, but it did not spread there, but it continued to spread in the rural, thinly scattered districts where one would not expect to find contagious disease. There was a resemblance to rabies. All those who have worked with this virus in laboratories were at once struck with the resemblance between poliomyelitis and rabies. The latter being a wound infection, there is some analogy between it and poliomyelitis, and poliomyelitis might be transmitted through some sort of wound. I was fortunate enough to have had experience with yellow fever, both in the investigation of it and the sanitary measures against it, before the mosquito period, and I was much struck with many analogies which came to me between that disease and certain features of poliomyelitis.

"The work I bring to your attention consisted of taking a number of flies,—*Stomoxys calcitrans,*—caught in a net and bred for the purpose; you can catch several hundred of these flies in a stable in a very short time. We placed these flies in a large cage and exposed monkeys to their bites, the monkeys having been purposely infected with the virus of poliomyelitis. Care was taken to place the monkeys in the cages in all stages of the disease, before and after. In fact a monkey would be exposed to the bites of the flies on the same day he was infected, so that the flies could drink the blood of the monkey during all stages of the period of incubation of the disease, for we do not yet know in what stage of the infection the virus appears in the blood at its maximum, or the best period for infecting these flies. Following this we exposed healthy monkeys to the bites of the same flies, and after several weeks' time these healthy monkeys came down with a disease which in all essential respects resembles anterior poliomyelitis. Out of twelve healthy monkeys so exposed, six of them now have symptoms of the disease, three of them in the virulent form. Of the other three monkeys, two are coming down, but one seems to have a milder infection than the other. This mild infection consists of trembling and weakness of the hand, and some weakness of the jaw which lasted about a week or so and then passed away. We cannot be sure whether that is true poliomyelitis or not until we are able to test the monkey subsequently. If it were poliomyelitis, that monkey would be 'immune.' In three of the six cases that came down with the disease, having been bitten by flies, there was some diarrhea. The disease in the monkey resembles more closely that which we see in children, rather than the disease we produce purposely experimentally by bringing the virus in direct association with the central nervous system. Of course, that may be only a coincidence, but it is interesting."

The work of Rosenau was repeated and confirmed during October, 1912, by Anderson and Frost[1] who summarize as follows: "Three monkeys exposed daily to the bite of several hundred Stomoxys, which at the same time were allowed daily to bite two intracerebrally inoculated monkeys, developed quite typical symptoms of poliomyelitis eight, seven and nine days from the date of their first exposure."

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[1] Anderson, John F., and Frost, Wade H., 1912. Transmission of poliomyelitis by means of the stable fly (*Stomoxys calcitrans*). U. S. Pub. Health Repts., Vol. XXII, No. 43, Oct. 25, 1912.

In order to verify the findings of the above experiments and to secure further biological evidence if possible the writer, in coöperation with Dr. W. A. Sawyer,[1] undertook a special investigation of the problem, beginning in October, 1912. Believing it unwise to use flies collected out of doors these insects were reared for the purpose in an insectary. The importance of this precaution is made evident by the fact that flies captured out of doors in Berkeley were shown to transmit a pathogenic organism to a rabbit, infection undoubtedly having been acquired in nature. This infection resulting in abscess was successfully transmitted from rabbit to rabbit through the agency of the Stomoxys fly.

> "In Rosenau's announcement he stated that the monkeys showed symptoms of poliomyelitis several weeks after the flies, which were biting them frequently, had had their first opportunity to receive infection from sick monkeys. This would allow abundant time for a definite biological change in the virus, preparing it, during the incubation in the fly as intermediate host, for successful inoculation into the warm-blooded monkey. Such a process seemed not an improbable explanation of the results when we considered that Rosenau was dealing with a blood-sucking insect and a disease in which the blood had been shown to have very low infectivity on direct inoculation. The symptoms of poliomyelitis in the experiments of Anderson and Frost appeared so soon after the first possible transference of infectious material that in all probability the process consisted of a mechanical transference of blood or other infectious material taken up by the flies while repeatedly piercing the skin. The extreme shortness of time available, in their experiments, for incubation of the virus in the fly is apparent when we consider that, in the interval of nine or ten days, we must allow also for the development of the virus in the original inoculated monkeys and for the incubation period in the monkeys infected by the flies." (Sawyer and Herms, *loc. cit.*)

Assuming the accuracy of the work of Rosenau and Anderson and Frost, it seemed advisable to plan the experiments so as to secure, if possible, an answer sooner or later to each of the following questions:

1. Is the Stomoxys fly merely a mechanical carrier of poliomyelitis or is it an intermediary host?
2. If it is an intermediary host how much time must elapse after biting before it can infect another animal?
3. How long does the fly remain infective?
4. How soon after infection does the experimental animal become infective to the fly and how long does the animal remain infective to the fly?

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[1] Sawyer, W. A., and Herms, W. B., 1913. Attempts to transmit poliomyelitis by means of the stable fly (*Stomoxys calcitrans*). Journ. Amer. Med. Assoc., Vol. LXI, pp. 461-466.

5. Does the severity of the infection increase with the number of bites of the fly?
6. What is the percentage of infected flies in nature?
7. Do other biting insects carry this disease?
8. Can other animals be inoculated by the Stomoxys fly and serve as carriers or receptacles of the disease, e.g. chickens, rabbits, guinea-pigs, rats, mice, pigs, dogs, cats, horses and cattle?
9. What are the best methods to exterminate the Stomoxys fly?
10. What precautions are necessary to prevent the existing flies from coming in contact with infectious patients and carrying the disease to other individuals?

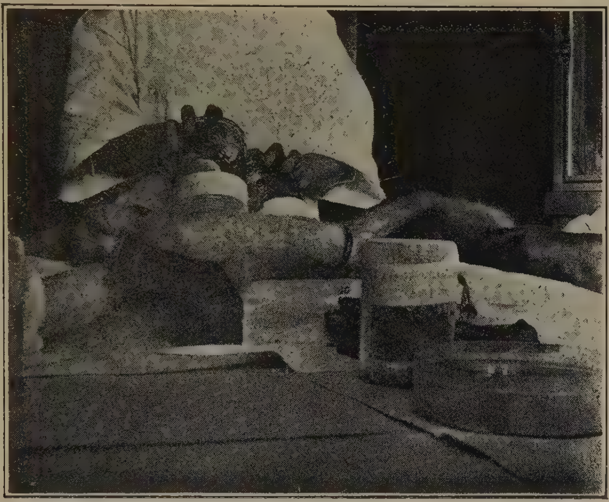

FIG. 146.—Showing jar method of feeding Stomoxys flies on monkeys. The jars are covered with bobbinet and sealed with adhesive plaster. The flies thrust their proboscides through the meshes and thus come in contact with the monkey.

A series of seven experiments was conducted covering a period of about nine months and involving the use of about four thousand laboratory-reared flies, a large number of monkeys, rabbits and other rodents. The experiments were carefully planned and every precaution was taken to bring about accurate results. In the first experiment approximately 1,750 flies were used, applying these to the animals in bobbinet-covered glass jars (quarts), 50 flies to a set (Fig. 146). A rhesus monkey was inoculated intracerebrally with 2 cc. of a suspension of Flexner virus, and the first set of flies was placed on this animal immediately after inoculation and after ten minutes' feeding transferred to a healthy monkey. The next day new sets of flies were used and again transferred to the same monkey, and those flies which had bitten the sick monkey on the previous day (24 hours ago) were placed to bite another unused monkey. In this way new flies were used each day and transferred immediately to the first healthy monkey; thus this animal always received flies that had fed for the first time on the sick monkey and transferred immediately. The second healthy monkey always received flies supposed to hold infection for 24 hours; the third animal, flies of 48 hours' standing; the fourth animal, flies of 4 days; the fifth animal, flies of 9 days; the sixth animal, flies of 17 days; the seventh, flies of 30 days; and the eighth received daily all the survivors of the entire series until all the flies were dead.

Between monkey feedings until the last animal was used, the flies were kept alive by allowing them to feed on rabbits every other day, a new rabbit being used each time. The rabbits remained healthy.

In the above experiment all the monkeys remained healthy except two; namely, the first one which received the virus, and that animal died on the fourth day of typical poliomyelitis, and the seventh animal, which died of acute pneumonia.

Except in cases of immediate transfer when only ten minutes of feeding was permitted, the flies were given ample opportunity to feed until satisfied (normally from 20 to 30 minutes) and ordinarily the flies fed well.

In the second experiment an immobilized inoculated monkey was placed in a screened fly cage (16″ × 28″ × 18″) with 500 Stomoxys flies. This animal remained in the cage with the flies for two hours, after which it was removed and a healthy monkey substituted (also immobilized). The second animal remained in the cage with the flies also for a period of two hours. This was repeated daily until the inoculated monkey died of poliomyelitis, after which the healthy animal was returned to the cage daily until all the flies were dead. The results proved negative.

In the third experiment the flies in jars as before to the number of about 600 were kept continuously under higher temperatures in the insectary,—temperature ranging from 23° to 26° C. The flies were applied for three minutes to the belly and chest of a diseased (poliomyelitis) monkey and then three minutes to the belly, chest and face of a healthy monkey, and thus exchanged back and forth at three-minute intervals until all flies had had a good chance to feed daily. After the death of the diseased monkey the flies were fed daily on the healthy monkey until all the flies were dead. The results were negative.

In the next experiment a fly filtrate, made of flies which had one hour previously fed on a monkey at the height of the disease, was inoculated, intracerebrally, into a healthy monkey with negative results, as also did a filtrate made from flies having fed four days previously.

In the fifth experiment large numbers of flies were applied daily at three-minute intervals between a poliomyelitis monkey and two healthy monkeys and continued daily on the latter after the diseased monkey died. The results were negative as before.

It was thought that possibly the results of the previous investigators had been due to the access of the flies to infectious material on the surfaces of the diseased monkeys and about their body orifices, hence a parallel experiment to the one above cited was undertaken with the difference that the abdomen and chest of the diseased monkey were painted, before the fly feedings, with a mixture of his saliva, his feces, and (late in the disease) his nasal washings in physiological salt solution. Even so the results were negative. Later, after the death of the diseased monkey, an emulsion of the highly infectious brain tissue was used in place of the mixture of feces, saliva and nasal secretions. The brain emulsion was painted on a normal monkey after which flies were applied and transferred as before to two other normal monkeys, all remaining well. Poliomyelitis had not been produced in a well monkey by stable flies even when they had to drive their proboscides through a layer of highly infectious brain tissue in order to pierce the skin, and the same flies did not transmit the disease on subsequent bitings of two other monkeys.

Conclusions.—From the above-cited experiments the following conclusions were drawn:

1. In a series of seven experiments in which the conditions were varied we were unable to transmit poliomyelitis from monkey to monkey through the agency of the stable fly.
2. Further experiments may reveal conditions under which the stable fly can readily transfer poliomyelitis, but the negative results of our work and of the second set of experiments of Anderson and Frost[1] lead us to doubt that the fly is the usual agent in spreading the disease in nature.
3. On the basis of the evidence now at hand we should continue to isolate persons sick with poliomyelitis or convalescent, and we should attempt to limit the formation of human carriers and to detect and control them. Screening of sick rooms against the stable fly and other flying insects is a precaution which should be added to those directed against contact infection, but not substituted for them.
4. The measures used in suppressing the house fly are not wholly applicable to the control of the stable fly owing to its different breeding habits and food supply.

Control.—The more important breeding places of the Stomoxys can be destroyed by removing the moist feed wastes from feeding troughs and from stalls, stables, etc., and scattering this material so that it dries out quickly. Considerable moisture is necessary for the development of the larvæ, therefore dry material is not suitable. Weeds, lawn cuttings, vegetables, rubbish, onions, etc., must not be permitted to accumulate in piles long enough to decay and accumulate moisture. The absence of stables does not insure against the Stomoxys fly even though it is called the stable fly. The commonest fly around stables is the house fly, while the Stomoxys may be entirely absent. This fly is near stables because of the blood of horses, cattle, etc., and not because suitable breeding material is commonly found there. Open country without stables is sometimes overridden with these biting flies.

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[1] Anderson, John F., and Frost, W. H., 1913. Poliomyelitis: Further attempts to transmit the disease through the agency of the stable fly (*Stomoxys calcitrans*). U. S. Pub. Health Reports. Washington, May 2, 1913, Vol. XXVIII, pp. 833-837.

Bishopp (*loc. cit.*) has shown that straw stacks (oats and wheat) are important breeding places of the Stomoxys fly, hence he recommends "that the straw for feeding and bedding purposes be baled and stored under cover. Where this is not practicable the stacks should be rounded up so as to make the top largely rain proof and the sides nearly vertical."

Repellent decoctions on domesticated animals only give temporary relief. Bishopp recommends as the most efficacious "a mixture of fish oil, oil of tar, and oil of pennyroyal with a little kerosene added."

Screening barns is recommended where flies are abundant.

Systematic.—The genus Stomoxys includes about ten species, of which *St. calcitrans* Linn. is the type, also the best known and most widely distributed species, occurring commonly on every continent.

Other species, all occurring in smaller numbers in restricted localities in Africa, are: *St. glauca* Grünb.; *St. inornata* Grünb. and *St. nigra* Macquart, which is said also to occur in the Philippines, but is considered a doubtful species by Grünberg.

C. The Horn Fly

Family Muscidæ, Genus Hæmatobia

Introduction.—*Hæmatobia serrata* R.Desv. (=*Lyperosia irritans L.*) is commonly called the horn fly, also known as the Texas fly. The former name is applied because this fly has the habit of clustering, often in great numbers, at the base of the horns of cattle. Though many believe the fly to injure the horn, there is no foundation for this belief. The position is probably only sought because it affords a safe resting place, especially at night.

As a cattle pest the horn fly has few if any equals; indeed, in the San Joaquin Valley (California) this fly is regarded as the most serious pest. The horn fly is a comparatively recent introduction into the United States from Europe, where it has been an important cattle pest for many years. According to the U. S. Bureau of Entomology it was first reported in the fall of 1887 from Camden, N. J., appearing during the following year in Maryland and Virginia, probably having appeared in Philadelphia in 1886 and by 1892 was found over the entire continent from Canada to Texas and from Massachusetts to the Rocky Mountains. California cattle men state that it made its appearance in this state in about 1893-1894. It appeared in Honolulu, Hawaii, in 1897.

Characteristics.—The horn fly is about half the size of the common house fly, i.e., about 4 mm. long. It has much the same color and in most other respects resembles the Stomoxys fly. The mouth parts (Fig. 147) are as in Stomoxys except that the labium is relatively heavier and the palpi are almost as long as the proboscis, are flattened and loosely ensheath the same. The arista is plumose dorsally. The wing venation is as in Stomoxys.

These flies appear early in spring and become most abundant in late summer and autumn. Both cattle and horses are attacked, but most especially the former. When at rest on the animal or elsewhere the wings lie flat on the back and fold rather closely, but when the fly bites, the wings are spread and the insect stands perpendicularly, almost hidden between the hairs of the host. Apparently the habit of resting at the base of the horns is only developed when flies are over-abundant.

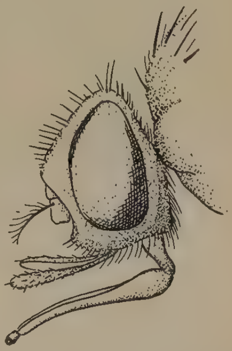

Fig. 147.—Side view of head of the hornfly, *Hæmatobia serrata.*

Life History.—The horn fly deposits its eggs chiefly, if not exclusively, on freshly passed cow manure. The fly is seen to dart from the animal and deposit its eggs in groups of four to seven, or singly, on the surface of the dung. The eggs are relatively large (1.3 to 1.5 mm.), larger than the eggs of Stomoxys; they are reddish brown in color, hence not easily seen on the cow dung. Under laboratory conditions, at least, few eggs are deposited by the females,—rarely over twenty. At a temperature of 24° to 26° C. the eggs hatch in 24 hours.

The larvæ burrow beneath the surface of the droppings, reaching full growth in from 3 to 5 days when they crawl underneath into drier parts and pupate. The pupal period requires from 6 to 8 days. Hence the entire life history (Fig. 148) from the egg to the adult requires from 10 to 14 days at a temperature of from 24° to 26° C.

Damage Done.—The damage occasioned by the horn fly is chiefly through irritation and annoyance which results in improper digestion and disturbed feeding, thus producing loss of flesh and reduction of milk in dairy animals. Dr. James Fletcher estimated the loss in Ontario and Quebec at one half of the product of meat and milk. Range animals literally run themselves thin in trying to get away from these pests.

The actual loss of blood must be considerable when literally thousands of these flies attack an animal. The weakened condition thus produced lays the animal liable to disease. From 10 to 25 minutes are required for the fly to fully engorge itself; during this time the fly withdraws and reinserts its proboscis in the same puncture many times as in a pumping motion. Much undigested blood is discharged from the anus of the fly while in the act of feeding.

Finally, though not absolutely proved, except through inference, the horn fly must certainly have the power of transmitting infectious blood diseases, such as anthrax. This problem has as yet not been touched by investigators.

Control.—The most effective method to prevent the multiplication of the horn fly is to scatter the droppings from cattle with a rake or other implements or simply by dragging a dry branch over the field. Hogs allowed to run with the cattle serve this purpose very well. The manure thus scattered dries out quickly and the larvæ if present perish owing to the fact that they require much moisture for development. The writer has seen this method applied most successfully in various parts of California where the dry summer favors this mode of handling the fly. On wide ranges this method is impacticable, but in connection with dairies it is entirely feasible. Piles of cow manure removed from stables afford a good breeding place for the Stomoxys fly, especially when straw predominates, but the horn fly is not favored in this way to any great extent. The manure should either be stored temporarily in fly-tight bins like horse manure, or spread on the field at once, or else placed in containers with water to liquefy the manure, the containers to be covered.

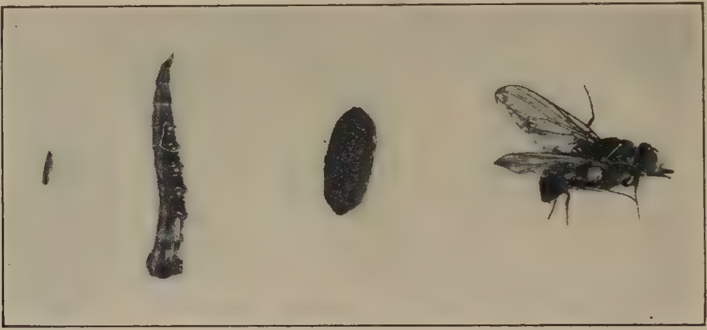

FIG. 148.—Life history of the "horn fy," *Hæmatobia serrata.* × 4.

Sprays used as repellents are of various kinds and of various efficiencies. Few sprays remain effective for longer than a day or so. Almost any oily, greasy substance is useful, but animals thus treated in the presence of dusty roads and pasture become very filthy in a short time. The usual ingredient in sprays for this purpose is fish oil or train oil, though petroleum sprays are also commonly used. The latter are not to be recommended for use on very hot days.

Petroleum sprays are used in the form of kerosene emulsion (crude petroleum, 2 gallons, ½ pound soft soap, 1 gallon soft water) one part to five parts of water. The Kansas Experiment Station (Press Bulletin No. 65) recommends the following mixture as both cheap and efficient: resin (pulverized), 2 parts; soap shavings, 1 part; water, ½ part; fish oil, 1 part; oil of tar, 1 part; kerosene, 1 part; water, 3 parts. The resin, soap, fish oil and ½ part water are boiled together until the resin is dissolved, then add the three parts of water and finally the kerosene and oil of tar. The mixture must be thoroughly mixed and boiled for fifteen minutes. The cooled mixture is then ready for use as a spray.

The application of the spray is done by means of a knapsack spray pump or other hand sprayer. One application seldom remains effective longer than three days, usually only a few hours. The addition of a little crude carbolic acid and sulphur is strongly recommended.

Washburn[1] states that "very fine tobacco dust sifted into the hair on the backs and where it will find lodgment, and the above wash (a mixture of fish oil and crude carbolic acid) applied to other parts which will not hold the dust, will obtain good results."

Smaller herds can be treated with ease by driving the animals through a narrow passageway, applying the spray as they pass between. On a larger scale it has been shown that dipping vat methods can be satisfactorily applied. The following is quoted from Circular No. 115, U. S. Department of Agriculture, Bureau of Entomology:

> "During the last three years, Mr. J. D. Mitchell, an agent of the Bureau, working with Mr. W. D. Hunter in Texas, has, in a study of the requirements for horn fly control, found that by a very simple modification of the ordinary dipping vat a very large percentage of the flies on cattle can be destroyed, with the consequent very notable limiting of the loss from the fly pest. With the vats as ordinarily constructed, most of the flies abandon the animal at the moment it plunges into the vat and escape, and go to other animals, and ultimately with the drying of the dipped animal return to it. Mr. Mitchell found, however, that by putting a splash board near the top of the vat on either side, about four feet above the level of the dip, the water thrown up violently as the animal plunges in, is caught by these splash-boards and is thrown back as a spray, filling the air space above the animal and drenching and destroying the flies in their effort to escape. The few of the horn flies that may escape, together with those which abandoned the animal at the entrance to the vat, were observed to hover or settle on the chute fence, and many would alight on the next animal coming along. He also found that where the animals have been heated in corralling and getting them into the chute the flies stick much closer and are much less apt to take quick flight, thus insuring the capture of a larger percentage of them by the dip and spray."

An oily dip must, of course, be used for this purpose.

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[1] Washburn, F. L., 1905. Diptera of Minnesota: two-winged flies affecting the farm, garden, stock and household. Univ. of Minnesota Agr. Exp. Sta. Bull. No. 93.

CHAPTER XVI

MYIASIS

Flesh Flies, Botflies, Warble Flies, etc.

Myiasis is a term referring to the presence of and resultant disturbances traceable to insect larvæ, primarily Diptera, in the intestine (*intestinal myiasis*), stomach (*gastric myiasis*), subcutaneous tissue (*dermal* or *cutaneous myiasis*), muscles (*muscular myiasis*), or ears (*auricular myiasis*, or *otomyiasis*) of vertebrate animals. The responsible insects may relate to myiasis in a more or less accidental manner, as is the case with certain root maggot flies, or they may be obligatory parasites, as is true of the bot and warble flies. The term *scholeciasis* is used to designate a myiasis caused by lepidopterous larvæ, and *canthariasis* when traceable to beetle larvæ.

Dipterous Larvæ.—The larvæ of Dipterous insects are footless and are commonly called *maggots*. Owing to the environmental setting of the parasitic species they may be mistaken for "worms" and are commonly so designated. Owing to differences in preventive measures insect larvæ and worms should be carefully distinguished. The dipterous larvæ are as a rule short and plump, measuring from 5 to 35 mm. in length (less in very young larvæ), and from 1 to 12 mm. in diameter; they are more or less cylindrical and tapering in form, and distinctly segmented, with ordinarily 11 or 12 visible segments (Fig. 13). All insect larvæ (as well as adults) possess an internal system of tracheated tubules, the respiratory system, which worms do not possess, hence with even a very minute portion of the parasite at hand, one can readily determine microscopically whether the specimen is insectan or not.

All nematode worms with which maggots might most easily be confused are non-segmented. Annelids with which insect larvæ might also be confused owing to their cylindrical, often plump form and their common segmentation, are easily distinguished from the fact that the former possess a larger number of segments (certainly over 20) and are devoid of tracheal tubules. Other important zoölogical characters are, of course, recognized.

A. The Flesh Flies

Order Diptera, Families Sarcophagidæ and Muscidæ

Characteristics.—The larvæ or maggots of the flesh flies are met with most frequently in myiasis of all forms. The adult flies are commonly known as blowflies. The great majority of the species deposit their rather conspicuous glistening white eggs on meat, dead animals, excrement or decaying vegetable matter; several species, notably the gray flesh flies (Sarcophaga), deposit living young. The blowflies are as a rule large flies, the smallest being about the size of the house fly; the wing venation is of the Muscid type; in color they vary from a bright metallic green and blue to gray; the thorax is more or less densely covered with bristles or heavy hairs (the Tachinid flies with which the Sarcophagids are most easily confused have tufts of very long spines on the tip of the abdomen, and the arista is bare). Classification of the species of flesh flies is largely based on the arrangement of the thoracic bristles (chætotaxy).[1]

Cochliomyia (*Chrysomyia*) *macellaria* Fabr. is the most important member of the family. This fly is commonly known as the *Texas screw worm fly*, probably because the larva (Fig. 149) is provided with intersegmentally arranged short spines and papillæ which give it a more or less screwlike appearance. The fly (Fig. 149) varies in size from 10 to 13 mm., dependent upon the growth of the larva; the ground color is a metallic green, with three longitudinal dark stripes on the thorax; the head is reddish to yellowish brown; the wings, when at rest, are commonly folded scissors-like over the abdomen; the wing venation is similar to that of the house fly (*Musca domestica*).

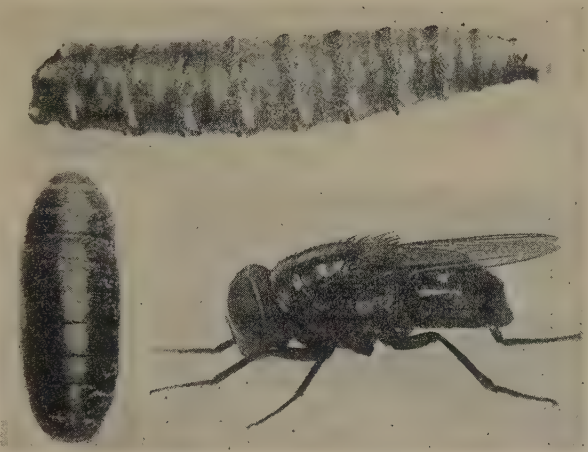
Fig. 149.—*Cochliomyia macellaria*, the Texas screw worm fly, larva and pupa. (After Bishopp.)

The screw worm fly is typically a North and South American fly ranging from Patagonia to Canada.

The following quotation will sufficiently explain the nature of the injury produced. (See Osborn, 1896, pp. 127-128, quoting Richardson in Peoria, Ill. Med. Mo. for February, 1883.)

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[1] For a detailed account of the ecological relationships of certain members of the Sarcophagidæ the reader is referred to the writer's work "An ecological and experimental study of Sarcophagidæ, etc." Journ. of Exp. Zoöl., Vol. 4, No. 1, pp. 45-83. Also "The sensory reactions of Sarcophagid flies, etc." Journ. of Exp. Zoöl., Vol. 10, No. 2, pp. 167-226.

"While traveling in Kansas in the latter part of last August, a citizen of this place had the misfortune to receive while asleep a deposit of eggs from this fly. He had been troubled for years with catarrh, hence the attraction to the fly. He returned home a few days after the accident and shortly after began complaining of a bad cold. Growing rapidly worse, I was called to attend him. Monday, my first day, his appearance was that of a man laboring under a severe cold. Had slight congestion of the lungs, and moderate fever. His nose seemed greatly swollen and he complained of a smarting, uneasy feeling in it, and general misery through the head. Gave him treatment to relieve the congestion and fever. Tuesday, saw him again. His nose and face were still swollen, and in addition to the other symptoms he was becoming slightly delirious and complained a great deal of the intense misery and annoyance in his nose and head. A few hours after, I was sent for in haste with the word that something was in his nose. I found on examination a mass of the larvæ of this fly (or 'screw worms' as they are commonly called in the South) completely blocking up one nostril. On touching them they would instantly retreat *en masse* up the nostril. Making a 20 per cent solution of chloroform in sweet milk I made a few injections up both nostrils, which immediately brought away a large number, so that in a few hours I had taken away some 125 of them. By Wednesday evening erysipelas had begun, implicating the nose and neighboring portions of the face. Another physician was called. By continual syringing with a strong antiseptic solution of salicylate of soda, bicarbonate of soda, and carbolic acid we hoped to drown out the remaining larvæ. But they had by this time cut their way into so many recesses of the nose and were so firmly attached that we were unable to accomplish much. Finally we resorted to the chloroform injections, which immediately brought away a considerable number. Friday I was able to open up two or three canals that they had cut, extracting several more that had literally packed themselves, one after another, in these fistulous channels. His speech becoming suddenly much worse, I examined the interior of his mouth and found that a clear-cut opening had been made entirely through the soft palate into his mouth and large enough to insert the end of a common lead pencil. Saturday the few remaining larvæ began changing color and one by one dropped away. On Sunday for the first time hemorrhage from both nostrils took place, which continued at intervals for three days, but was not at any time severe. On this day the patient began to improve, the delirium and erysipelas having subsided, leaving but little or no annoyance in his head. In a few days he became able to go about home, and even to walk a distance of half a mile to visit a friend and return. But while there he began complaining of a pain in the neighborhood of his left ear, apparently where the eustachian tube connects with the middle ear. It proved to be an abscess. Being already so reduced by the first attack he was unable to withstand the second, and died after an illness of nearly three weeks, completely exhausted by his prolonged sufferings. Three days before his death the abscess discharged its contents by the left nostril. The quantity of pus formed was about 2½ ounces (78 grams).

"In all about 250 larvæ were taken away from him during the first attack, and, as the visible results, not only had they cut the hole through the soft palate, but had also eaten the cartilage of the septum of the nose so nearly through as to give him the appearance of having a broken nose. The case occupied, from the first invasion of the fly to its final result, nearly two months. He doubtless would have recovered but for the formation of the abscess, which, from all the symptoms, was caused by one or more of the larvæ having found their way up the left eustachian tube."

Life History.—The screw worm fly overwinters most commonly in the pupal stage, but also as an adult as do the bluebottle and greenbottle flies. *Cochliomyia macellaria* deposits eggs normally within its southern range, the time for hatching varying from less than an hour to twelve or more hours. But there is some difference of opinion as to its habits in its northern range. The writer has carried on careful observations on this fly during several summers along the southern border of Lake Erie and has never observed this fly to lay eggs. Living young were invariably deposited. Others (notably Hine) maintain that eggs are deposited. It is quite possible that the latter is true earlier in the season.

The eggs or larvæ to the number of 200 to 500 are deposited on dead animals ordinarily, or in wounds or sores of domesticated or wild animals. Human beings are frequently attacked in the nostrils. The growth of the larvæ is very rapid, full size being reached in three days under optimum conditions. The fully grown maggots vary from 12 to 15 mm. in length; food shortage (except when very great) as a rule only results in smaller larvæ and smaller flies.

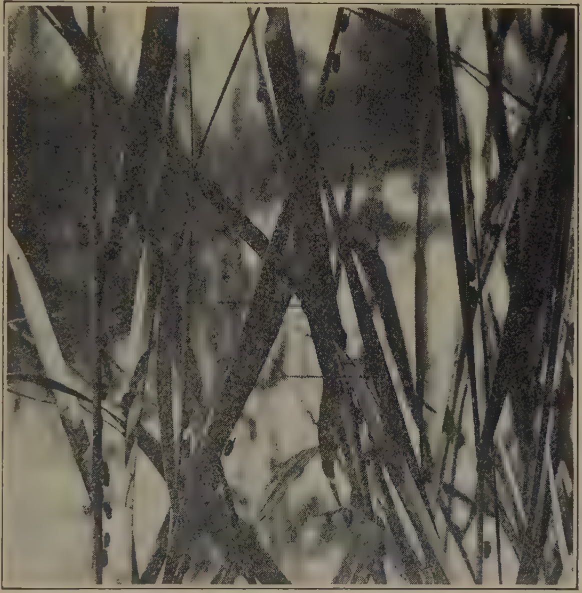

Fig. 150.—Texas screw worm flies just emerged from the pupa cases. A dead animal near by furnished food for the larvæ, pupation took place in the sand underneath the carcass. The newly emerged flies have crawled up on the grass and will soon be ready to fly away. Note characteristic resting attitude, with head down.

When fully grown the larvæ leave the carcass or wound, bury themselves in loose earth or débris immediately beneath or near by, and enter the pupal stage in 2 or 3 days. The pupæ are chestnut-colored, barrel-shaped, rather rough and fairly characteristic, measuring from 5 to 8 mm. in length. Under optimum conditions the pupal stage requires 4 days.

On emergence from the pupal cases the flies crawl out of the sand or dirt and climb up nearby grasses, weeds or shrubbery, where the wings are spread. The screw worm fly at this time almost invariably turns about with its head downward after it has reached a resting place. (Fig. 150.) Thus one often finds great numbers of flies in some restricted spot without an apparent explanation for their presence, the dry skin and bones of the dead fish or other small animals having blown away or having been covered by sand or dust. The total life history of the screw worm fly from egg (or maggot) to imago is nine days at its shortest to two weeks and over under less favorable conditions.

As Affecting Man the attacks of the screw worm are largely limited to individuals suffering from nasal catarrh or unclean from vomit or with open sores or wounds. Sleeping individuals or persons in a drunken stupor are most liable to be attacked, although the fly has been known to dash successfully into the nostrils of wide-awake individuals, in which case the fly is usually not permitted to remain in the nostrils long enough to oviposit. Even so it is wise to properly syringe the nasal passages.

As Affecting Domesticated Animals.—According to Osborn cattle suffer most from the ravages of screw worms, in which they occur in wounds from horns, castrating, spraying, branding, dehorning, barbed wire injuries, and often where ticks have burst on the brisket, flank or just behind the udder of cows. They often occur in the vulvæ of fresh cows, especially if there has been a retention of the placenta or afterbirth. Young calves are almost invariably affected in the navel, and often in the mouth, causing the teeth to fall out.

Horses and mules are not so often attacked, and if so, the maggots are usually found in barbed wire injuries, and occasionally in the sheaths of horses and the vaginæ of mares and the navels of colts.

Hogs on the other hand are more liable to become affected than horses, since they are frequently wounded by dogs and by fighting or there may be barbed wire injuries, wounds from castration, etc.

"Sheep are attacked when injured by dogs; or when the sheep are in poor condition the eggs are laid upon the wool, and when the larvæ hatch they immediately bore into the skin. In many cases the sheep are attacked within the nasal cavities and the worms eat into the head." The reader is warned against confusing these maggots with the true head maggot (*Œstrus ovis*).

Treatment for Nasal Myiasis in Humans.—Treatment for maggots in the frontal sinuses and other cavities must be given without delay, owing to the rapid growth of the maggots and their terrible destructive work. Injection of a remedy is necessary. Some of the more useful remedies are "20 per cent solution of chloroform in sweet milk, a few injections up both nostrils," repeat until larvæ are expelled; or carbolic acid 2 per cent; or infusion of pyrethrum; or turpentine. A saturated solution of common salt will cause only a portion of the larvæ to be expelled but is not to be disregarded in the absence of more useful remedies, until a physician arrives.

Treatment for Animals.—After locating the point of infestation, indicated by purulent sores, or small eaten openings, surrounded by elevations which shift or disperse suddenly when touched, the expulsion of the maggots must be brought about by the introduction of an insecticide. Ordinarily a weak solution of carbolic acid (1½ to 2 per cent), pyrethrum infusion, chloroform, creolin or chloronaphtholeum is injected. This may be done as recommended by Francis by means of a machinist's oiling can. The larvæ must then be carefully scraped out and the wound dressed with pine tar or other curative agent. Pine tar will also act as a repellent against further attack by flies.

Preventive Measures.—To prevent immediate attack by flies, animals should be carefully examined for open wounds, wire fence cuts, etc., so as to apply treatment and repellents to prevent the deposition of eggs.

Inasmuch as the flies involved in myiasis breed very abundantly in dead animals, all carcasses should be burned without delay or buried deeply and the body liberally covered with chlorid of lime, crude oil or creosote. Burning is preferable by far. Superficially buried carcasses are easily reached by the young maggots hatching from eggs deposited on the ground above the body. Proper and expeditious disposal of all dead bodies, such as rats, cats, dogs, or larger animals, also of slaughter house refuse, kitchen garbage, manures, etc., will certainly reduce the myriads of flies which are a menace to the health and well-being of both man and beast on the farm.

Wool Maggots.—Blowflies, inclusive of the screw worm fly already discussed, were undoubtedly at one time solely scavengers feeding in the maggot stage on carrion and animal wastes, but with the introduction of herds of domesticated animals acquired the habit of attacking living animals. Froggatt[1] writes:

> "It is frequently stated, and with a certain amount of truth, that the 'blow-fly pest' was known in New South Wales forty years ago, but it was only in isolated cases and under exceptional conditions that live wool was then blown. The fact that rams' heads often became maggoty in summer time through their polls being cut and bruised while fighting has led to the statement that the flies blew wool in far distant days, but the almost universal infestation of otherwise healthy sheep, simply because the wool of the crutch, rump or flanks becomes wet and stained has only become a real menace to sheepowners within the last twenty-five years.
>
> "Blow-flies have always been in Australia, and under natural conditions before such disturbing elements as cattle, horses, sheep, and rabbits were introduced, they were simply scavengers or flesh-flies that deposited their

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[1] Froggatt, W. W., 1922. Sheep-Maggot Flies. Farmers' Bull. No. 144, Dept. of Agric. New South Wales. 32 pp.

eggs in animal matter that happened to be festering in the sun. In the study of economic zoology the acquisition of new habits by an insect is no uncommon occurrence. In the case of the blow-fly we know that first some one species learned the habit of blowing live wool from the practice (already acquired) of blowing the wool of sheep that had died from some other cause. The smell of the dead wool taught them that the damp or soiled wool on a live sheep was of a similar character, and once the maggots set up decomposition of the yolk and fibre the smell attracted other flies. Thus other species became sheep-maggot flies until all our common blow-flies had learned the habit.

"To upset the balance of nature is always a dangerous undertaking, and there is not much doubt that it has been the destruction of the natural means of control of the fly and the provision of a much larger number of suitable breeding-grounds that has caused the remarkable increase in the number of flies. After great droughts landowners have had to fight millions of rabbits breeding all over the West, and poisoned water and poison-carts have been put to considerable use. Sometimes the dead rabbits were stacked up and left to rot; sometimes they filled up the water-holes; sometimes they were piled up feet high along the wire-netting fences. It can be easily understood that under such conditions the blow-flies must have increased a millionfold. Again, the poisoning of dingoes and rabbits has caused the death of many of our hawks and carrion crows, and I feel quite sure that one of these birds in tearing up a carcass will often kill far more maggots than a dozen of the smaller insectivorous birds that capture the flies, but often only after they have deposited their eggs on the sheep.

"The next, and perhaps the most important factor in the development of the sheep-maggot pest, is the work of sheep-breeders themselves. Forty years ago there were many thousands of Merino sheep of the bare-belly, bare-legged type, which did not produce a third of the weight of wool of the modern, improved Merino. The ambition of every sheep-breeder has been to make every inch of the sheep's skin grow wool, and in the case of some classes of Merinos to produce a wrinkled skin, giving even more wool-bearing surface. A sheep clothed with such a mass of thick, close, fine wool, fitting closely over the rump and round the tail, is sure to get more or less stained and damp round the crutch, and to attract flies. This artificial increase in weight, quantity and fineness of wool is accompanied, too, by an increased secretion of yolk, which, rising from the skin and spreading all through the wool fibre, forms an additional attraction for the flies, and supplies food for the maggots."

The following species of flesh flies are listed by Froggatt and other authors as attacking live wool, *Phormia regina* Meig. known as the black blowfly because of its blackish-blue color and regarded as the most important wool-maggot fly of Texas and California; *Lucilia sericata* Meig., resembling *Lucilia caesar* Linn. very closely but being brighter because of the stronger coppery color, an important sheep maggot fly in Australia and other parts of the world; *Chrysomyia albiceps* Wied. = *Chrysomyia* (*Pycnosoma*) *rufifacies* Macq., common in Australia and India; *Chrysomyia macellaria* Fabr. a menace to sheep raising particularly in the Southern States of the United States, Mexico and elsewhere in the range of this insect; *Chrysomyia bezziana*

Ville = *Chrysomyia flaviceps* Wlk. = *Chrysomyia dux* (Esch.), an important Australian and Oriental sheep maggot fly; *Wohlfahrtia magnifica* Schin., the principal sheep maggot fly of southern Russia, also causes human myiasis in Egypt.

Control of Wool-Maggot Flies.—The following recommendations for the control of wool maggot flies are suggested by Babcock and Bennett[1] of the Texas Agricultural Experiment Station and by Froggatt (*loc. cit.*): (1) *Carcass burning,*—dig a trench along the back of the carcass nearly as wide as the animal and as long, and twelve to fourteen inches deep; fill trench with wood (one-quarter cord of wood sufficient to burn cow or horse) or cow chips; start fire at windward end and entire carcass will be entirely consumed within twelve to twenty-four hours. (2) *Poisoning,*—a freshly killed animal is very attractive to flies, and if treated with an arsenic solution will kill every fly that feeds on it, or if a carcass is already alive with maggots, a similar treatment will kill these also. For this purpose arsenite of soda at the rate of three pounds to thirty gallons of water is recommended. (3) *Screening,*—by placing four upright stakes at each corner of a fly-blown carcass and covering well with sacking to catch the emerging flies which are left to die for want of food and moisture. (4) *Trapping,*—large fly traps properly placed and baited with a small dead animal (cut open) or entrails will assist in reducing the flies. (5) *Crutching,*—if properly done prevents the attack of flies by reducing the opportunity for the wool of the crutch, rump and flanks to become wet and soiled and thus attractive to flies. (6) *Jetting,*—applying an arsenic solution (one pound of arsenic to forty gallons of water) by means of a single jet under pressure of 125 pounds to the rump of the sheep: in this way the arsenic is forced through the wool to the skin, where it dries and protects the animal for a longer time than spraying. (7) *Parasites,*—the use of parasites against the flies is advocated and *Nasonia brevicornis,* a common chalcid wasp, has been bred in great numbers in New South Wales and is being successfully used as a parasite of the fly pupæ.

Foot Maggots.—A lameness that varies in degree and traceable to myiasis, commonly occurs in Philippine cattle, carabaos and goats and is caused by the larva of *Boöponus intonsus* Ald. Woodworth and Ashcraft[2] state that the eggs of this fly are attached to the hairs of the lower portions of the legs of the host animal, the incubation period varying from 3 to 5 days. The young larvæ work their way down to the coronary and neighboring parts and enter the flesh, leaving their posterior ends exposed and when full grown at the end of 2 to 3 weeks they leave the flesh and drop to the ground where they bury themselves and pupate, the pupal period requiring about 10 days.

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[1] Babcock, O. G., and Bennett, D. H., 1921. The screw worm and the wool maggot. Texas Agric. Exp. Sta. Circ. No. 27. 15 pp.

[2] Woodworth, H. E., and Ashcraft, J. B., 1923. The foot maggot, *Boöponus intonsus* Aldrich, a new myiasis-producing fly. Philip. Journ. of Sci., Vol. 22, No. 2, pp. 143-156 (8 plates).

The method of treatment suggested by these authors consists of cleaning the affected area with soap and water, removing as many maggots as possible and applying a chloroform pack, followed by heavy applications of *pix liquidæ* every third day until the lesions heal. As a preventive means, daily inspection is recommended of all cattle, carabaos and goats, especially during the dry season when the animals should have access to plenty of water and mud as wallows.

Toxic Effect of Ingested Fly Larvæ.—A disease known as "limberneck" in chickens is believed to be traceable to the ingestion of large numbers of fly larvæ (*Lucilia caesar, Lucilia sericata* and no doubt other species of flesh flies) or meat infested with type C *Bacillus botulinus.*[1] It is believed that the organism multiplies in the unburied bodies of dead animals, as meat is a favorable medium for growth, and that the flesh flies developing in the carcasses become infected and in turn chickens eating the maggots (or the meat) acquire the infection. This is another good reason why dead animals should be speedily and safely disposed of, preferably by incineration.

Other Flesh Flies.—The larvæ of several species of flesh flies are frequently met with in gastric and intestinal myiasis. This is accounted for by the presence of very young maggots in meats which are eaten cold and not carefully masticated. Nausea and gastric disturbances may be traceable to this form of accidental myiasis. Owing to the small amount of oxygen available the growth of the larvæ must needs be very slow. Larvæ brought to the attention of the writer have been seldom more than 4 or 5 mm. long.

The flesh flies deposit their eggs commonly on cold meat, particularly pork, if exposed to flies. The eggs hatch in from 8 to 24 hours under summer conditions and the larvæ grow rapidly.

The larvæ of practically all the species of flesh flies already mentioned also occur frequently in wounds in domesticated animals and man, producing injury similar to that of the screw worm.

The larvæ of the blowfly or bluebottle, *Calliphora vomitoria* Linn. and *C. erythrocephala,* Mg. are also commonly met with various forms of myiasis. The two species of flies are not usually differentiated, the two names being applied indiscriminately. *C. vomitoria,* however, has black genæ with golden red hairs, while *C. erythrocephala* has fulvous genæ with black hairs (Fig. 151). The eggs of these species hatch in from 6 to 48 hours, the growing larvæ feed on the flesh for from 3 to 9 days, after which the fully grown larvæ leave the food and bury themselves in loose earth. This period (prepupal period) lasts from 2 to 7 days, commonly 4, after which pupation takes place. The pupal period varies considerably according to temperature, lasting from 10 to 17 days, commonly 11 days. Thus the life history of the blowfly requires from 16 to 35 days, commonly 22 days. The life of the adult is about 35 days on an average.[1]

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[1] Bengtson, Ida A., 1923. A toxin-producing anaerobe isolated principally from fly larvæ. U. S. Public Health Reports, Vol. 38, No. 8, pp. 340-344.

Lucilia caesar Linn., the greenbottle fly, is not so commonly found indoors and is typically a scavenger fly. The life history of this species is somewhat shorter than that of the bluebottle. The egg stage requires from 6 to 48 hours; the growing (feeding) larval stage requires from 3 to 7 days, commonly 5 days; the prepupal period, commonly 6 days; and the pupal period from 8 to 34 days, commonly 12 days, giving a total of from 16 to 60 days and over, commonly 24 days. Under optimum conditions this fly invariably *requires* 15 days for its metamorphosis; the average longevity of the fly is about 30 days.

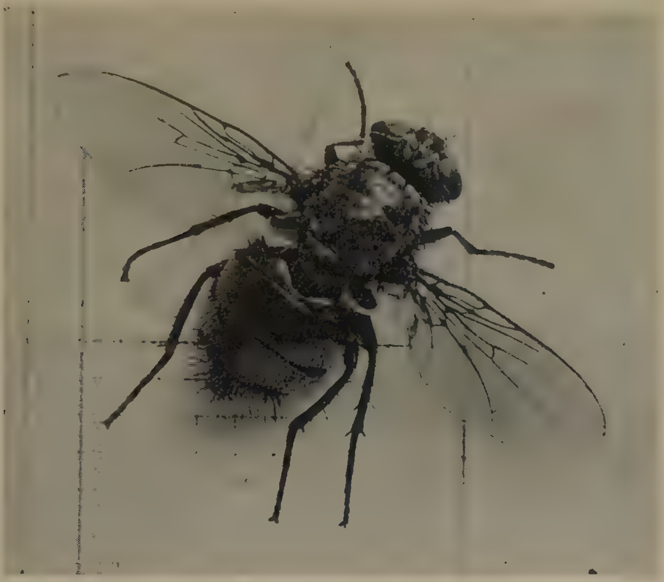

FIG. 151.—A common blow fly, *Calliphora vomitoria.*

Sarcophaga sarraceniæ Riley is a typical flesh fly, has the appearance of an overgrown house fly, but is lighter gray, has a spiny thorax, brighter reddish brown eyes and is viviparous. It resembles very closely the larger species of parasitic Tachinid flies, but has not the strongly developed terminal abdominal spines. The young are deposited on meat, or if extruded in the vicinity of meat not accessible to the fly, the larvæ crawl to the food. The larval stage under optimum conditions requires about 5 days, and the pupal period about 13 days.

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[1] Herms, W. B., 1911. The photic reactions of Sarcophagid flies, etc. Contributions from the Zoöl. Lab. of the Mus. of Comp. Zoöl., Harvard, No. 217.

Wohlfahrtia vigil (Walk.) was taken in Toronto by Walker[1] in three cases of cutaneous myiasis. The case of a five-months-old boy is described, viz.:

> "Most of the lesions were clustered together on the left side of the neck under the angle of the jaw, one being on the left cheek. They had been first noticed by the mother 24 hours earlier, and when seen by the writer they were already secondarily infected with pus organisms, the child being in a poor general condition and suffering from an intestinal disorder. They were similar to the lesions observed in the previous cases, each being a boil-like sore with an external opening, and from these openings five or six larvæ had already been expressed. Only three additional larvæ were obtained, these measuring 5 to 7 mm. in length. Each was placed on raw beef in a separate test-tube, plugged with cotton wool. In 24 hours they reached a length of 12 to 13 mm. and in another 24 hours they were full-grown, each measuring about 17 mm. in length.
>
> "On the third day after their removal from the child the larvæ were placed with the meat in a jar of earth and immediately burrowed into the latter. Next day they were at the bottom of the jar and two of them had begun to contract. Three days later they were dug up and all had transformed into puparia.
>
> "On September 27, 18 days later, a male *Wohlfahrtia vigil* emerged. I waited for the others to appear until October 5, but neither having emerged by that time I opened one of the puparia on that day and the other a week later, and in both I found pupæ which had evidently died some time before the proper time for emergence, as they were quite colorless. In this case, like the previous ones, the child recovered rapidly after the removal of the maggots."

Creosote Oil.—It has been found that surfaces treated with creosote oil are repellent to flies for many days and that dead bodies completely covered with it so as to prevent maggots from gaining a foothold do not become invaded. From a half to a gallon is said to be sufficient for a horse carcass. The skin quickly hardens and becomes leathery, the body remaining well preserved for weeks, it is said.

Sodium Cyanid.—Under oriental conditions innumerable flies (said to be *Chrysomyia spp.*) originate in the receptacles (*feng gang*) used to store human excrement. This dangerous condition is undoubtedly responsible for much of the dysentery that exists during the fly season. Professor C. W. Woodworth who has spent considerable time in China has informed the author that a remarkable reduction in the fly population of Nanking was brought about by the application of a solution of sodium cyanid (one ounce to a gallon of water) to the contents of the vessels. The cyanid solution was applied by means of a sprinkling can when found necessary on inspection.

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[1] Walker, E. M., 1922. Some cases of cutaneous myiasis with notes on the larvæ of *Wohlfahrtia vigil* (Walker). Journ. of Para., Vol. 9, No. 1, pp. 1-5 (3 plates).

Tumbu Fly and Congo Floor Maggot.—Several African species of flesh flies are commonly referred to in the literature on myiasis, among them *Cordylobia anthropophaga,* E. Blanch., the "tumbu fly," the larvæ of which burrow beneath the skin, developing there as do the larvæ of the warble fly, *Hypoderma.* It is said that babies are particularly liable to be attacked by the "tumbu fly." Austen describes it as being a "thickset, compactly built fly, of an average length of about 9½ mm. . . . Head, body and legs straw color. . . ." Another species commonly found in the same locality with the above is *Auchmeromyia luteola,* Fabr. The larva is a blood-sucker and is known as the "Congo floor maggot." (Fig. 152.) The two species are said to resemble each other closely but Graham-Smith[1] states that "the two species may be distinguished by the fact that in *A. luteola* the eyes are wide apart in both sexes, the body is narrower and more elongate, the hypopygidium of the male is in the form of a conspicuous, forwardly directed hook, for which the ventral half of the penultimate segment of the abdomen segment in the female is twice the length of the same segment in the male. . . ."

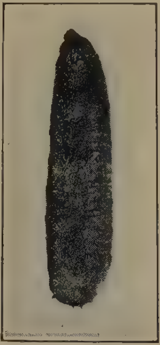

FIG. 152. — The Congo floor maggot, *Auchmeromyia luteola.* × 2.5.

"The full-grown larva is a fat, yellowish white maggot, 12 to 12½ mm. in length, bluntly pointed at the anterior or cephalic extremity, and truncate behind; its greatest breadth (on the sixth and seventh segments) is 5 mm. The body consists of twelve visible segments, the divisions between which are strongly marked, except between the cephalic and first body segment (the latter of which bears the anterior or prothoracic stigmata, or respiratory apertures), and between the eleventh and twelfth segments. On the underside of the cephalic segment the tips of the black paired mouth hooks may be seen protruding, while in a slight depression in the flattened posterior surface of the twelfth segment are situated the paired posterior stigmatic plates. In the adult larva the slit-like apertures in these plates are not very easy to distinguish, but in a maggot in the second or penultimate stage, it is seen that each plate bears three ridges of tawny colored chitin; these ridges run obliquely downwards and outwards, at an angle of 45° from the median line, and, while the median ridge on each plate is nearly straight, the other two ridges are characteristically curved, resembling inverted notes of interrogation, with the concavity directed towards the median ridge. The segments of the body are transversely wrinkled on the dorsal and ventral surfaces (especially on the latter), and puckered on the sides. From the third to the eleventh segment the body is thickly covered with minute recurved spines of brownish chitin (darker in the case of larvæ ready to leave the host), usually arranged in transverse series or groups of two or more, which can be seen to form more or less distinct, undulating or irregular, transverse rows. These spines will be described in somewhat greater detail below.

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[1] Graham-Smith, G. S., 1913. Flies in relation to disease,—non-blood-sucking flies. Cambridge University Press. xiv + 292 pp.

"Above and to the outer side of each mouth hook is an antenna-like protuberance, which, as in the case of the larva of the blowfly (*Calliphora erythrocephala* Mg.), exhibits a pair of light brown, ocellus-like spots, or rather papillæ, placed one above the other. In a small larva, 5 mm. in length, from Lagos, the papillæ are very clearly visible; each papilla is surrounded by a ring of pale brownish chitin, and its shape, when viewed from the side, is exactly that of a muzzle of an old-fashioned muzzle-loading cannon.

"This small larva also shows on the basal segment of each antenna, or antenna-like protuberance, below and a little to the outer side of the mouth hook, a prominence bearing a series of about six small, brown tipped, chitinous spines. In the same larva the spines on the body are most conspicuous, and most strongly developed and chitinized, on the fifth, sixth and seventh segments. The tenth and eleventh segments are also covered with spines, but, since the chitin of which they are composed is not tinged with brown, these segments appear bare. In the adult larva also, the spines of the tenth and eleventh are less conspicuous than those on the preceding segments; on the twelfth segment, which bears the posterior stigmatic plates, the spines are very minute. Fully chitinized spines are dark brown, but this color is generally confined to the apical half of the spine, or may be absent from the extreme base. In shape each spine is a short cone, with the apex recurved, pointing towards the hinder part of the body. The spines are broad at the base in proportion to their length, and not infrequently, especially on the under side of the body, are bifid at the tip. They are closest together and most strongly developed on the anterior portion of each segment, becoming smaller and showing a tendency to disappear towards the hind margin. They are arranged in irregular transverse rows, which are usually seen to be composed of from two to five spines, placed side by side.

"In the adult larva the median area of the ventral surface of the segments five (or six) to eleven inclusive is marked with a series of three transverse ridges, which are most prominently developed on the seventh and following segments. On each segment the foremost ridge is the shortest; next in length comes the hindmost, and the middle ridge is the longest of the three, curling round the posterior ridge at each end. Similar but less strongly marked ridges are seen on the dorsal surface.

"*Puparium.* Of the usual barrel-shaped Muscid type. Average dimensions: length 10⅓, greatest breadth, 4⅔ mm. Though at first of a ferruginous or light chestnut tint, the puparium gradually darkens until it becomes 'seal-brown' or practically black."

Manson (*loc. cit.*) states that the fly deposits its eggs in the dust-filled cracks and crevices of the mud floors of native huts, particularly in spots where urine is voided. The duration of the larval life has not been determined. The larvæ suck blood mainly at night. The pupal stage is said to require from two to three weeks.

Other Blood-Sucking Maggots.—In a study of blood-sucking fly larvæ in birds' nests Plath[1] found an average of 61 per cent of a total of 63 nests examined to be infested with an average of 47 maggots per nest. The species of birds were Nuttall sparrow, California purple finch, Greenback goldfinch, Willow goldfinch and California brown towhee. In a later paper the same author[1] adds several other species, namely, Rusty song sparrow, Cliff swallow, Oregon towhee, Yellow warbler, Western robin, Russet-backed thrush and Cedar waxwing. The species of flies responsible for the maggots were found to be *Phormia azurea* Fallen, *Phormia metallica* Town., both flesh flies, and *Hylemyia nidicola* Ald., an anthomyid fly.

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[1] Plath, O. E., 1919. A muscid larva of the San Francisco Bay Region which sucks the blood of nestling birds. Univ. of Calif. Publ. in Zoöl., Vol. 19, No. 5, pp. 191-200.

Plath concludes that from 5 to 10 per cent of the parasitized nestlings die from loss of blood, and some of them which do become full fledged are so weakened by the loss of blood that they fall an easy prey to rapacious animals.

B. Anthomyid Flies

Order Diptera, Family Anthomyidæ

Characteristics.—The Anthomyid flies are usually grayish in color, non-metallic, resembling the house fly. The first posterior cell of the wings is broadly open. The mouth parts are of the house fly type. The larvæ are often vegetable feeders, either in living roots or in decaying vegetation, also in manures. The metamorphosis is complex as in the house fly.

Because the maggots of the Anthomyid flies are commonly found in onions, radishes, turnips and other roots and vegetation, their relation to human myiasis is easily understood, particularly when the vegetable is eaten uncooked. Several species of Anthomyid larvæ have been recovered in human cases, notably *Fannia* (*Homalomyia*) *canicularis*, *F. scalaris*, *Anthomyia radicum*.

Fannia (*Homalomyia*) *canicularis* L., commonly known as the *lesser house fly*, is frequently seen hovering in mid-air or flying hither and thither in the middle of the room. Where the common house fly is encountered most abundantly in the kitchen or dining room, particularly on food, the "little house fly" will be seen as commonly in one room as another, and very seldom actually on the "spread" table. The writer commonly observes a half dozen or more of these little flies dancing weirdly in the center of the lecture room midway between the floor and the ceiling. Various observers have estimated that this species constitutes from one to 25 per cent of the total population of flies in the house.

In size the species varies from 5 to 6 mm. Its color is grayish, resembling the house fly very closely. Hewitt describes the male, viz.:

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[1] Plath, O. E., 1919. The prevalence of *Phormia azurea* Fallen (larva parasitic on nestling birds) in the Puget Sound Region and data on two undescribed flies of similar habit. Ann. Ent. Soc. of Amer., Vol. XII, No. 4, pp. 373-381.

> "Head iridescent black, silvery white, especially around the eyes. The antennæ are blackish gray with non-setose arista. Palps black. The thorax is blackish gray with three indistinct black longitudinal stripes; the scutellum is gray and bears long setæ; the sides of the thorax are lighter. . . . The legs are black, and the middle femora bear comb-like setæ below. The somewhat large squamæ at the bases of the wings are white and the halteres are yellow. . . . The head of the female is gray with a wide frons, black frontal stripe and gray sides. The longitudinal stripes of the thorax are faint and the abdomen, which is more pyriform than that of the male, has a slightly golden attachment."

The eggs of this species are deposited on decaying vegetable matter and excrement, particularly of humans, horses and cows. The larvæ emerge in about 24 hours and may be recognized as compressed, spiny organisms about 6 mm. long when full grown (Fig. 153 left). The pupal period lasts about seven days under favorable conditions.

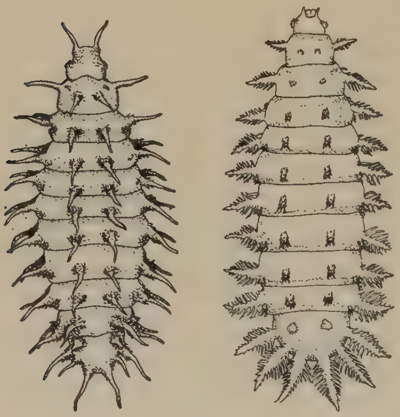

Fig. 153.—(*a*) Larva of *Fannia* (*Homalomyia*) *canicularis;* (*b*) Larva of *Fannia* (*Homalomyia*) *scalaris.* (Redrawn and adapted after Hewitt.) × 6.

Fannia (*Homalomyia*) *scalaris* Fab., the latrine fly, is very similar to the foregoing. In size the two flies are about the same, if anything the latrine fly is somewhat the larger. The thorax and abdomen are bluish black, the antennæ and palpi are black as are the legs. The abdomen has a dark median stripe which, with segmentally arranged transverse bands produces a series of dorsal triangular markings. The middle tibia is provided with a distinct tubercle.

The eggs of this fly are deposited on excrement of humans, horses, cows, etc., also on decaying vegetable matter. The egg stage lasts about 24 hours, the larval stage about 6 days and over, and the pupal stage about 9 days.

While the larva of the "latrine fly" resembles the larva of the lesser house fly in general, it is readily distinguished by the single lateral protuberances being distinctly feathered (Fig. 153 right).

Anthomyia radicum Linn., the root maggot fly of Europe, is described by Meade, according to Slingerland[1] viz.:

> "It may be recognized by its projecting face; by the scales of the base of the wings being unequal in size; by the thorax being black and marked

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[1] Slingerland, M. V., 1894. The cabbage root maggot, with notes on the onion maggot and allied insects. Cornell University Agr. Exp. Sta., Bull. No. 78, pp. 481-577.

in the male by two short, gray, narrow stripes; by the rather short, wide, somewhat pointed abdomen, with a longitudinal dorsal black mark, crossed by three transverse straight black stripes extending of an equal width to the margins; and by the third and fourth longitudinal veins of the wings being slightly convergent at their extremities. This inequality in the size of the alular scales, the shape of the abdomen, the markings on the body, and the convergence of the third and fourth longitudinal veins of the wings are characters, any one of which would distinguish the male fly, at least, from the cabbage fly" (*Phorbia brassicæ,* Bouché).

Anthomyia radicum is a typical root maggot fly, its larvæ developing in the roots of radishes and other plants; Bouché records the maggots as developing in human excrement. According to Slingerland (*loc. cit.*) this author gives 8 to 10 days as the period required to pass through the egg and larval stage and 2 or 3 weeks for the pupal stage. Hewitt (*loc. cit.*) gives the egg stage at from 18 to 36 hours, the larval stage at about 8 days and the pupal stage about 10 days.

The fully grown larvæ measure "8 mm. in length and may be distinguished by the six pairs of spinous tubercles surrounding the posterior end and a seventh pair situated on the ventral surface posterior to the anus. The tubercles of the sixth pair, counting from the dorsal side, are smaller than the rest and are bifid" (Hewitt). The ingestion of the larvæ with uncooked vegetables not thoroughly masticated, seems to be the mode of infection.

Relation to Gastric and Intestinal Myiasis.—Many cases of intestinal myiasis traceable to Anthomyid flies are recorded. (See Parasitology, Vol. 5, No. 3, pp. 161-174.)

"The presence of these larvæ in the stomach is usually indicated by nausea, vertigo and violent pains; the larvæ in many cases are expelled by vomiting. If they occur in the intestine, they are expelled with the feces and their presence is signalized by diarrheal symptoms, abdominal pains or hæmorrhage caused by the traumatic lesions of the mucous membrane of the intestine which the larvæ affect" (Hewitt).

Mode of Infection.—As has already been explained, the eggs of these flies may be deposited upon decaying or even fresh vegetable matter or excrement, in which the larvæ develop. It seems quite probable that the young larvæ (possibly also the eggs) are taken into the stomach in uncooked food. It is also suggested (Hewitt) that the flies may deposit their eggs in or near the anus, particularly in the use of old-fashioned open privies. The larvæ on hatching are believed to make their way into the intestine.

Larvæ in the Urinary Tract.—Infestation of the urinary tract by larvæ of *Fannia canicularis* is by no means uncommon according to Chevril.[1] The expulsion of larvæ with the urine in both sexes has been recorded. Entrance into the urinary tract is undoubtedly gained by the larvæ through the genital openings (of females primarily), to which the adult flies have been attracted by secretions on exposure of these parts during sleep or drunken stupor.

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[1] Chevril, R., 1909. Sur la myase des voies urinaires. Arch. de Parasitol., XII, pp. 369-450.

C. RAT-TAILED LARVÆ

Order Diptera, Family Syrphida

Characteristics.—The family Syrphidæ includes a very large group of flies, many of which are brightly colored, varying greatly in size. They are nearly all flower loving, feeding on nectar mainly. Only one genus needs be considered here, namely Eristalis, the larvæ of which have a long anal breathing tube, i.e., "rat-tailed," and the adults are commonly called drone flies.

Eristalis tenax Linn., the drone fly (Fig. 154), is a rather large insect, somewhat larger than a honeybee and resembles the drone bee very closely; indeed, is commonly referred to as its mimic. The fly deposits its eggs on liquid manure or other filthy liquids in cans, slop jars, privies, septic tank effluent, etc. The larvæ are known as "rat-tailed larvæ" (Fig. 155); these also occur occasionally in heaps of horse manure.

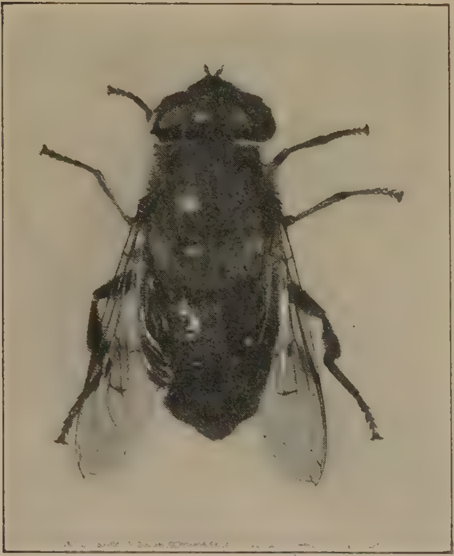

FIG. 154.—The drone fly, *Eristalis tenax*, whose larvæ are commonly called "rat-tailed larvæ." × 3.5.

Relation to Myiasis.—The frequency with which the "rat-tailed" larvæ occur in liquid excrement must lead to extreme caution in accepting reports that these larvæ have been evacuated with discharges from the bowels. The writer has on several occasions received specimens of "rat-tailed" larvæ which were said to have been evacuated by the "double handful" and that the patient had "steadily improved" thereafter.

There are, however, several cases on record which seem to be incontrovertible, notably the case reported by Hall and Muir,[1] who also bring together all recorded information to date relative to Eristalis and myiasis. The case referred to was that of a boy aged five years "who had been ailing for about ten weeks and who was under medical treatment for indigestion and obstinate constipation for about five weeks at that time. The child was emaciated and anemic. Very striking symptoms were the constant and pronounced twitching of the eyelids and other nervous movements. He gritted his teeth in his sleep at times, and made convulsive movements of the limbs. When awake he complained of pain in the limbs and headache. The emaciation seemed to be due to the fact that the boy had for some time vomited almost everything he ate. The breath was very bad, 'worse than rotten eggs' according to his parents. On the basis of the nervous and digestive disturbance and the general debility, a diagnosis of worm infestation was made."

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[1] Hall, M. C., and Muir, J. T., 1913. A critical study of a case of myiasis due to Eristalis. Archives of Intern. Med., Vol. II, pp. 193-203.

With this diagnosis in mind the mother of the boy gave him a dose of a proprietary worm remedy, resulting in the discharge of an object wriggling round vigorously in the feces and urine. The slop jar into which the stool was passed was in regular use and had been previously rinsed with tap water and allowed to dry during the day. The specimen was identified by the authors as one of the "rat-tailed larvæ" measuring 3.2 cm. in length, including the long "tail." A second larva was said to have been discharged the following day. The case is believed by the authors to be probably a genuine case of "gastric myiasis."

After the passage of the larvæ the child is said to have improved in health and became normal, the nervous symptoms and vomiting disappeared.

FIG. 155. -The "rat-tailed larva" of *Eristalis tenax*, drone fly. × 2.

Three chances for infection are pointed out; namely, first, the eating of "overripe" or probably decaying peaches in which "rat-tailed" larvæ might have occurred; or, secondly, to the drinking of "ditch" water polluted with kitchen refuse, etc.; or, lastly, to stable manure in a neighbor's yard where the child played.

The authors offer the following comment relative to the gastric disturbances:

> "A larva supplied with the stigmatic apparatus of *Eristalis* would apparently be fitted for life in a stomach with a small amount of food and plenty of the atmospheric air which is swallowed in eating and drinking and at other times. Such a condition would simulate the normal life

conditions fairly closely. That the stomach would not fill to the point where it would drown the larva might be insured by the vomiting, perhaps automatically, the activity of the larva increasing as the stomach filled to where it threatened to cover the rising stigmatic tube, and so setting up an irritation leading to vomiting. The mother states that the child's stomach was extremely intolerant of milk and that drinking milk was promptly followed by vomiting. This suggests that milk, usually taken in long drinks and considerable quantities, quickly threatened the larva with drowning and set up such activity as promptly to cause vomiting."

Hall[1] has added the records of other cases giving a total of seventeen, claiming the presence of syrphid larvæ in the digestive tract of man; one claiming their presence in the nostrils of man; and two claiming their presence in the diseased vagina of cattle.

D. Botflies

Order Diptera, Family Œstridæ

Characteristics of the Œstridæ.—The Œstridæ are described by Williston as follows:

> "Flies of moderate to rather large size, thick-set, usually more or less pilose. Head large, the lower part more or less swollen. Antennæ short, three-jointed, decumbent, and more or less sunken in the facial groove or grooves; arista bare or plumose. Mouth opening small, the mouth parts sometimes rudimentary, never large. Front broad in both sexes, in the male broader in front. Eyes comparatively small, bare. Ocelli present. Thorax robust, with a distinct transverse suture. Abdomen short, conical or but little elongated; genitalia of the male hidden, the ovipositor sometimes elongated. Legs moderately long, the hind pair sometimes elongated. Tegulæ usually large; sometimes small. Neuration of the wings muscid-like, in most cases the first posterior cell narrowed or closed; anal cell small, usually indistinct; discal cell sometimes absent.
>
> "This family, though of small size, is of the greatest interest by reason of the habits of the larvæ, all of which that are known are parasitic upon mammals. The adult flies often have rudimentary mouth parts, and devote the whole of their brief existence to the labors of procreation. . . . Parasitism occurs in three principal ways, in the stomach and digestive tubes, in tumors formed by the larvæ under the skin and in the pharyngeal and nasal cavities. With but few exceptions each species is confined to a single species of mammal, and each genus or each group of allied species is parasitic in the same way upon similar animals."

a. Horse Bots

Characteristics.—*Gastrophilus intestinalis* De Geer = *Gastrophilus equi* Fabr. is the common horse bot (Fig. 156). This species is described by Osborn, viz.:

> "Adults of this species are about 18 mm. in length, the wings are transparent with dark spots, those near the center forming an irregular trans-

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[1] Hall, M. C., 1918. A note regarding myiasis, especially that due to syrphid larvæ. Arch. Int. Med., Vol. XXI, pp. 309-312.

verse band. The body is very hairy, the head brown with whitish front, thorax brown, abdomen brown with three rows of blackish spots, which are subject to considerable variations. In the females the segments are often almost entirely brown with simply a marginal series of yellowish spots, while in the males the abdomen may be almost entirely yellow or very light brown, with brown or dark brown spots very distinct. The males are rarely seen, for while it is one of the most common occurrences to witness the females around the horses depositing their eggs, the males evidently hold aloof. They are readily distinguished by the form of the abdomen, which lacks the two tubular segments at the end, and is provided on the under side of the last segment with a pair of dark brown or black hooks, or clasping organs. Otherwise, except the color of the abdomen, already mentioned, they resemble very closely the females."

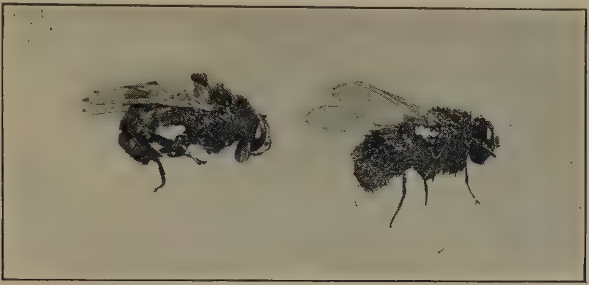
FIG. 156.—The horse botfly, *Gastrophilus intestinalis*. (Female, left; male, right). × 1.6.

Life History.— The eggs (Fig. 157), which are light yellow, are attached to the hairs of the forelegs, belly, shoulders and other parts of the body. The female fly may be seen hovering two or three feet away from the horse, when it is seen suddenly to dart at the animal, fastening an egg firmly in place. This process is repeated until perhaps several hundred eggs may be attached. The very careful observations of Osborn (and corroborated in the main by the writer) indicate that "the eggs normally require friction and (probably) moisture to permit of their hatching and transfer to the horse's mouth, that hatching occurs with difficulty before the tenth day, and most readily after the fourteenth day, and that they lose vitality at a period varying between the twenty-eighth and fortieth days, the bulk not surviving more than four weeks." The newly hatched larva is a very spiny creature (Fig. 158) which readily adheres to moist surfaces, hence must easily adhere to the rough, moist lips of the horse, passing into the mouth and gradually working its way down the esophagus to the stomach, where it attaches itself to the mucous lining by means of the strong oral hooklets. The stomach wall often becomes so crowded with bots that

FIG. 157.—Eggs of the horse botfly, attached to a hair of the host. × 20.

there is hardly room for a finger to touch the stomach without coming in contact with them (Fig. 159).

The bots remain attached, usually in the esophageal portion of the stomach, growing slowly throughout the rest of the summer, autumn and winter, until late spring, when full growth is reached, having molted twice during this time. They are then from 1.5 to 2 cm. long (Fig. 160). At this time the insects let go, gradually pass out through the intestine with the feces and drop to the ground. Reaching the ground, the bots burrow into loose earth and in a few days pupate. The pupal period varies considerably, depending upon moisture and temperature conditions, but the usual time is from three to five weeks, when the winged flies emerge. Copulation takes place soon, inasmuch as the insects probably partake of little or no food; egg laying begins again in early summer, and as new individuals emerge continues until autumn.

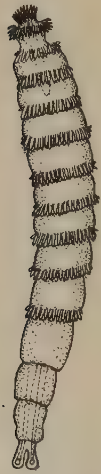

FIG. 158. — Newly emerged larva of the horse botfly. × 60.

Pathogenesis.—While a moderate infestation of bots will give no outward indications, a heavy infestation will be indicated by digestive disorders (which may of course be traceable to other causes as well). The discovery of bots in the manure is sufficient evidence. A light infestation is probably of no consequence,—there are indeed some individuals who erroneously maintain that a horse must have at least a few bots in order to be well.

The injury which bots produce is: (1) abstraction of nutriment, both from the stomach and its contents; (2) obstruction to the food passing from the stomach to the intestine, particularly when the larvæ are in or near the pylorus; (3) irritation and injury to the mucous membrane of the stomach due to the penetration of the oral hooklets; (4) irritation of the intestine, rectum and anus in passage.

Treatment.—Internal remedies are always best and most safely administered by a veterinarian. However, Washburn[1] states that carbon bisulphid has been used in Italy with marked success. Six gelatine capsules, each containing 15 grains of CS_2, were given to two horses at intervals of two hours. During the four following days the first horse passed 497 bots; the second, in five days, 571 bots. Another party gave one horse 32 grains in five hours, and the animal passed 203 bots. Horses so treated should be carefully watched, and if any bad effects appear, treatment should be stopped. Hall[2] has also found carbon bisulphid highly effective.

[1] Washburn, F. L., 1905. *Loc. cit.*

[2] Hall, M. C., 1917. Notes in regard to bots, Gastrophilus spp. Journ. Amer. Vet. Med. Assoc., Vol. 51, N. S., Vol. 5, No. 2, pp. 177-184.

Prevention.—The object in view is to prevent the botfly larvæ from gaining entrance to the mouth of the horse, hence control methods involve the egg. The first method that presents itself is to prevent the fly from depositing its eggs on the horse. This can be done by keeping the animals stabled during the day, giving them free range at night.

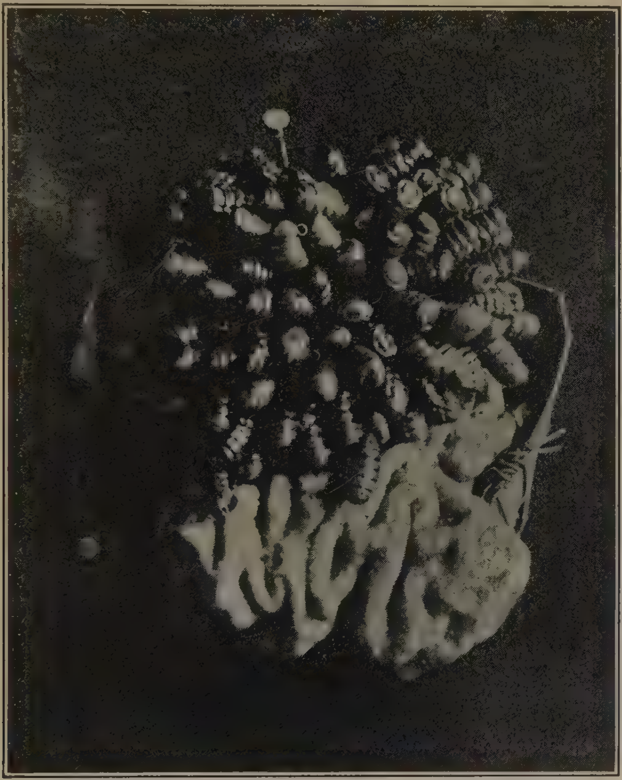

FIG. 159.—Horse bots (*Gastrophilus intestinalis*) attached to inner lining of the stomach of a horse. (Photo by Wherry.) × .75.

A second method involves the destruction or removal of the eggs from the horse. Touching the eggs lightly with kerosene, benzine or gasoline proves effective. The eggs are easily removed with a sharp razor or clippers, in which case treatment is unnecessary.

Based on our knowledge of the egg stage it would seem that very few bots would reach the stomach of the horse if the animal is treated as above at least once every two weeks.

If internal remedies are administered and the bots are full grown or nearly so, it is safer to treat the manure copiously with kerosene or carbolic acid in order to destroy the larvæ to prevent pupation and emergence of the flies.

Other Species of Horse Bots.—*Gastrophilus hæmorrhoidalis* Linn. is the red-tailed bot, or nose fly. This species is about 1.5 cm. in length with an orange-red-tipped abdomen. "The thorax is olive-gray and hairy, with a black band behind the suture. The base of the abdomen is whitish and the middle blackish, in strange contrast with the orange-red of the end." The eggs of this species are dark brown to nearly black and are deposited on the long hairs of the horse's lip.[1] The incubation period is very much shorter than in *G. equi.* The larvæ find their way into the mouth on food or with the tongue in licking, and eventually reach the stomach. The fully grown larvæ are from 12 to 15 mm. long. Law describes the larvæ, viz.: "The spines are arranged in a double row on each ring, but on the dorsal aspect they are absent in the middle of the ninth ring, while on the tenth and eleventh there are none. The larvæ pass the winter mostly attached in groups in the left sac of the stomach, but also in the right sac, and duodenum, and exceptionally in the pharynx."

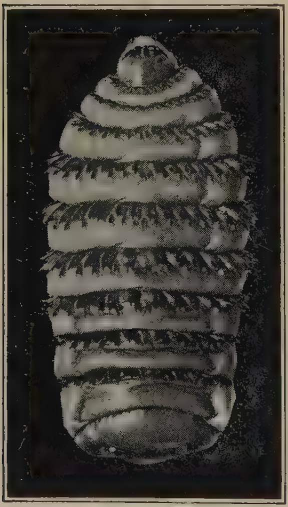

Fig. 160.—Larva of *Gastrophilus intestinalis,* the horse bot. × 4.

"When mature and passing out through the intestines they often hook themselves for a time to the rectal mucosa, where they cause considerable irritation and rubbing of the tail. They also pass through the anus independently of defecation, and hook themselves to the skin round its outer margin, causing rubbing and switching of the tail, and a stiff awkward gait. This habit, with that of laying the eggs on the lips and jaw, and of hooking on the delicate mucosæ of the pharynx, right gastric sac and duodenum, renders this one of the most injurious of the Œstridæ" (Osborn).

The pupal stage is entered soon after the bot drops to the ground and buries itself, and lasts from four to six weeks and over. The flies occur from early summer to late autumn.

Gastrophilus nasalis Linn. is the chin fly, which measures about 1 cm. in length. It is "densely hairy, with the thorax yellowish red or rust colored. The abdomen is either whitish at the base, with the middle black and the apex yellowish brown and hairy, or the base is whitish and all the rest brown; or the middle is black; with the base and apex whitish, with grayish hairs. The wings are unspotted" (Verrill).

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[1] In a brief article published by R. R. Parker in the Journ. of the N. Y. Ento. Soc. (Vol. 24, No. 4, pp. 253-255) it is stated that the nose fly in "striking" thrusts the stalked ends of eggs direct into the skin of the lips and nose.

The white eggs are deposited on the lips or around the nostrils. The larvæ are "furnished with a row of spines on each ring from the second to the ninth on the dorsal surface, and as far as the tenth on the ventral. There is an unarmed part in the center of the eighth and ninth rings on the dorsal surface. It spends the winter attached to the mucosa of the commencement of the duodenum, usually in clusters, and is rarely found in the stomach. In passing out it shows no tendency to hook itself to other parts of the intestine or the anus" (Law).

The remainder of the life history is as in other species already described.

Gastrophilus pecorum Fabr. is about the same size as *G. intestinalis.* In color it is yellowish brown to nearly black. The wings are brownish and clouded. In egg deposition, life history and habits this species resembles the latter very closely. It is said to be rare or absent in the United States.

b. Ox Warbles

Warbles in Cattle.—The backs of both European and American cattle commonly show numerous swellings during late winter and early spring traceable to larvæ of flies belonging to the genus Hypoderma. Horses, mules and other animals, including man, are occasionally affected. Each of the warble tumors is inhabited by a large-sized fly larva. Two species of warble flies are recognized,—*Hypoderma lineatum* Villers, also known as the "heel fly," and *Hypoderma bovis* De G., both of which are widely distributed. The former occurs in every state in the United States, while the latter has a more northerly distribution with greatest abundance in the northeastern states, particularly Vermont.[1]

Specific Characters.—*Hypoderma bovis* is the larger of the two species, measuring about 15 mm. in length, while *H. lineatum* measures about 13 mm. The former has the thorax covered with dense yellow hairs in front and black behind with the terminal yellow hairs on the abdomen, while the latter (*H. lineatum*) (Fig. 161) has a fairly uniform hairy covering of mixed brownish-black and white with four prominent smooth and polished lines on the thorax, the hairs of the terminal segment of the abdomen being reddish orange. The full grown larvæ are easily distinguished by an examination of the spiny armature,—thus *H. bovis* has the last two segments entirely devoid of spines, while *H. lineatum* has only the last one smooth. It may also be said that the full grown larva of the former measures from 27 to 28 mm. in length and the latter about 25 mm. (Fig. 162).

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[1] Bishopp, F. C., 1915. The distribution and abundance of the ox warbles, *Hypoderma lineata* and *H. bovis* in the United States. Ann. Ento. Soc. of Amer., Vol. VIII, pp. 359-364.

Life History and Habits.—The eggs of both species are laid on the hairs of cattle, *H. lineatum* attaching as many as a dozen in a row to a single hair, while *H. bovis* is said to attach but a single egg to a hair. As many as 800 eggs it is stated, may be laid by a female of either species.[1] The eggs are evidently deposited by preference on the legs from the hock to the knee of the standing animal, but in recumbent animals the eggs may be attached to the hairs of other parts of the body close to the ground. Although no pain is inflicted at the time of oviposition cattle become terror-stricken when the fly is discovered and gallop madly for water in which to stand to escape the enemy. This is termed "gadding" and often spreads to the whole herd.

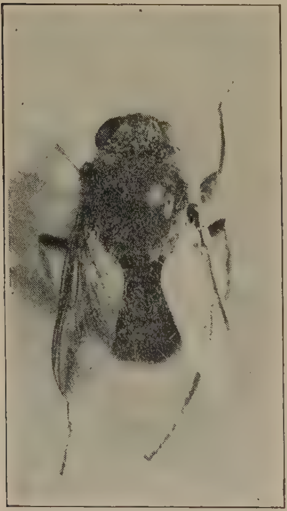

Fig. 161.—The ox warble fly, *Hypoderma lineatum*. × 2.6.

The eggs of both species hatch within a week and the tiny armored larvæ crawl down the hairs of the host and bore either directly into the skin or into the hair follicles.[2] From this time on (June to August, both inclusive) the course of the larvæ is unknown until they appear in the wall of the esophagus (September to November) which gave rise to the idea that the larvæ were licked off by the host animal and found entrance by way of the mouth. This mode of entrance is now believed to be exceptional.

From their position in the connective tissue of the esophagus the larvæ now quite smooth and measuring about 14 mm. in length migrate downwards to the wall of the stomach and thence, always in the connective tissue, to the region of the back, many of them passing through the spinal canal. Having reached a suitable position the larvæ now molt again (five larval instars are now recognized) and the grub as it is commonly known is formed. A cyst is developed and a tumorous swelling results with the posterior end (spiracular) of the larva closely appressed to a hole which it has made in the skin of the animal to secure air. The warbles begin to appear in the backs of cattle in some parts of California about January 1 and Warburton reports mid-February as the time when the indications of newly-forming dorsal tumors are the most numerous in England.

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[1] Warburton has presented a most satisfactory account of "The Warble-Flies of Cattle" in Parasitology, Vol. 14, Nos. 3 and 4, pp. 322-341.

[2] Hadwen, S., 1915. Warble flies,—a further contribution on the biology of *Hypoderma lineatum* and *Hypoderma bovis*. Parasitology, Vol. VII, No. 4, pp. 331-338 (2 plates).

During late spring and early summer the mature larvæ emerge from the tumors through the holes made for breathing, drop to the ground and crawl away into the loose earth or débris, becoming rapidly dark brown to black in pupation and in from 4 to 5 weeks emerge as warble flies.

Injury Done.—The injury done by the warbles is first that of *irritation* caused by their migrations in the body of the animal and later in their emergence from beneath the skin; secondly, the escape of the larva from the tumor leaves an open, running wound which persists for a long time and is attractive to screw worm flies and other tormenting insects. The direct pathogenesis is of minor importance, however, in the face of the economic loss produced by this insect.

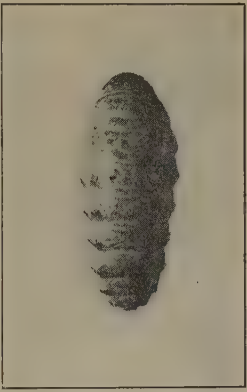

FIG. 162.—Larva or grub of the ox warble fly, *Hypoderma lineatum*. × 1.3.

Economic Losses.—The economic losses produced are: (1) Reduction in milk secretion, which is estimated at from 10 to 20 per cent of the normal yield. (2) Loss of flesh due to the wild endeavor of the animals to escape from the flies and the irritating larvæ (which is pointed out by Holstein, viz.: "A cow quietly grazing will suddenly spring forward, throw up her tail, and make for the nearest water at a headlong gait. Seemingly deprived at the moment of every instinct except the desire to escape, she will rush over a high bluff on the way, often being killed by the fall. This, with miring in water holes and the fact that cattle are prevented from feeding, causes the loss"). (3) Depreciation of the value of the carcass as flesh, which becomes greenish yellow and jelly-like in appearance at the points where the grubs are located, and is not fit for consumption. (4) Injury produced to the hide which becomes "grubby," full of holes where the grubs have emerged (Fig. 163).

The following is quoted from *Tanners' Work* for October, 1913:

> "The case is recorded by Boas of Denmark of a cow which remained in poor condition and gave 33 pounds of milk per day. Forty-six grubs were extracted from this animal and eight days later she was giving 44 pounds of milk per day, continued to do so most of the summer and was in good flesh and condition in the fall. In this case the loss of milk due to the grub infestation was 25 per cent. The loss in flesh on account of grubs has been variously estimated at from \$1.00 to \$5.00 or more per head. If we assume that 25 per cent of all of the cattle in the United States are more or less infested with grubs, a quite conservative estimate, 50 per cent probably being nearer the actual percentage, the loss in flesh on account of grubs amounts to from \$15,000,000 to \$75,000,000 a year, the total number of cattle in the United States being calculated as approximately 60,000,-

000. If we also assume that infested milch cows lose 10 per cent in milk production and that 25 per cent of the 20,000,000 milch cows in the United States are affected, there should be added to the account a loss of not less than $30,000,000 per year.

"As to the loss in hides it is stated by European tanners that a grubby hide is, on the average, less in value by one third than a perfect hide, but for this country, I have no definite information other than that grubby hides in the green state are commonly valued at 1 cent a pound less than perfect hides. On this basis the depreciation in value of a hide of average weight of 65 pounds if grub-infested, would be 65 cents and the depreciation in the value of the estimated 15,000,000 grubby cattle of the United States so far as their hides are concerned thus amounts to $9,750,000. It is, however, quite probable that the actual loss in the value of hides when made into leather is much greater than this.

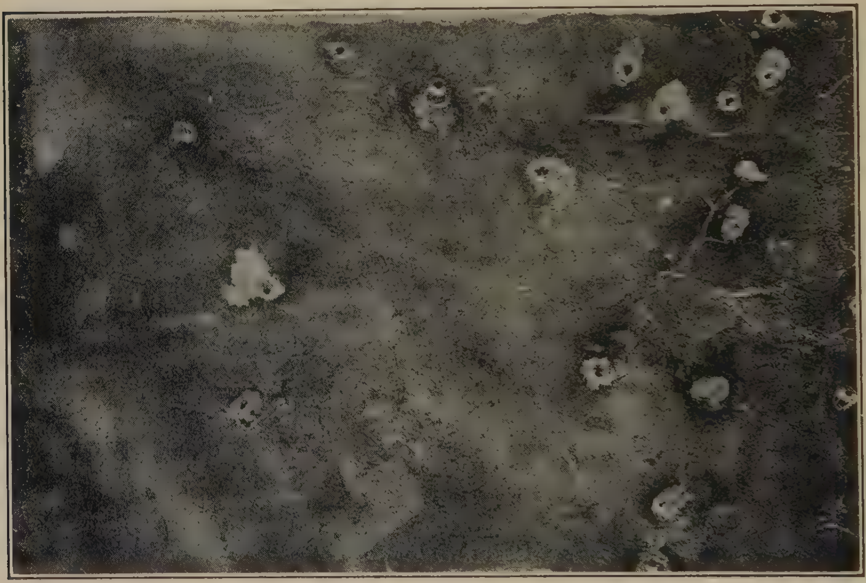

FIG. 163.—A piece of sole leather 21 × 31.5 cm. showing work of ox warble. × .3.

"Without including the loss on account of the direct damage to beef carcasses from the presence of grubs, we may, on the basis of the foregoing, estimate the total loss from grubs in the United States in round numbers at from $55,000,000 to $120,000,000 per year."

Treatment.—The tumors in which the grubs occur may be treated with kerosene, benzine, turpentine or carbolic acid, a few drops of which are introduced into the opening by means of a machinist's oiler, or merely smeared over the surface. Ointments of sulphur and vaseline are also serviceable. These remedies are objectionable inasmuch as the grubs are not eliminated, dying within the tumor where they must be slowly absorbed; serious abscesses may result.

The grubs may also be destroyed *in situ* with a sharp scalpel or a hot needle, but here again the same objection as above is encountered.

A better method is to remove the grubs bodily, which can easily be done by squeezing them out if the grubs are about ready to leave the tumors. If not easily squeezed out, a forceps with slender blades may be introduced into the opening, the grub grasped and eliminated. In some cases the use of a lancet may be needed to widen the opening in the tumor. The use of a properly constructed suction syringe applied when the grubs are "ripe" would no doubt give good results.

After removal the grubs must be destroyed to prevent further metamorphosis, and the wound should be treated with a carbolated salve.

Prevention.—Owing to the fact that the eggs hatch very soon after deposition, treatment with kerosene, benzine or gasoline would have to be given as soon as the eggs are noticed. This treatment is not particularly practical but is not to be disregarded.

Removal of the grubs or treatment of the same prevents the completion of metamorphosis and hence results in the reduction of the number of adult flies for the next season.

Associations for the eradication of grubs have been formed in Europe, which cope with the problem through educational methods. In some districts a bounty is offered from ½ cent to ⅚ cent per grub. Their efforts have given very good results. No practical method of eradication in range animals is at hand, but certainly there is no reason why with proper coöperation and systematic effort this evil could not be controlled where only smaller herds are concerned, thus actually saving large sums of money to the stock raiser and dairyman.

c. Head Maggot of Sheep

Characteristics.—*Œstrus ovis* Linn. is the botfly of sheep, or the sheep gadfly, the larva of which is the common head maggot of these animals. "Grub-in-the-head," "false gid" and "staggers" are common designations.

The fly (Fig. 164) is somewhat larger than the common house fly, dull yellow or brownish in color and hairy. The abdomen is variegated with brown and straw yellow, the feet are brown. It is further described by Osborn as follows:

> "The under side of the head is puffed out and white. The antennæ are extremely small and spring from two lobes which are sunk into a cavity at the anterior and under part of the head. The eyes are purplish brown, and three small eyelets are distinctly visible on the top of the head. It has no mouth and cannot, therefore, take any nourishment. The wings are transparent and extend beyond the body, and the winglets (calypteres) which are quite large and white, cover entirely the poisers. It is quite lazy, and, except when attempting to deposit its eggs, the wings are seldom used."

Life History.—The head maggot fly deposits living young from early summer to autumn in the nostrils of sheep and goats and may also attack human beings. These at once begin to migrate up the nasal passages, working their way into the nasal sinuses often as far as the base of the horns in rams and attach themselves to the mucous membranes. Here numbers of these whitish grubs may be found wedged in closely in various conditions of development (see Fig. 166). The posterior ends which are unattached present conspicuous spiracles. The grubs (Fig. 165) reach full growth with a length of from 25 to 30 mm. by the following spring,—a larval period of from 8 to 10 months. At the end of this time they let go, wriggling their way out of the nostrils, fall to the ground, bury themselves in the earth and pupate in a few hours. The pupal period lasts from 3 to 6 weeks and over.

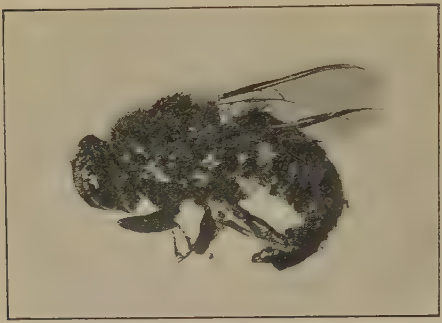

Fig. 164.—Head maggot fly (*Œstrus ovis*) of sheep. × 4.

Symptoms.—In the presence of the fly the sheep are very much excited, shake the head, rush with their noses between their fellows, push their noses into the dust, snort and otherwise indicate that they are trying to escape something that persists in entering the nostrils. Once infected there is a purulent discharge from the nostrils, vigorous shaking of the head, and perhaps occasional discharge of a maggot, loss of appetite, grating of the teeth, and when the animal walks the fore feet are lifted in a pawing movement.

The great majority of the cases do not result fatally, but death often results in a week more or less after the appearance of aggravated symptoms.

Grub-in-the-head is distinguished from "gid" (caused by a larval tapeworm. *Cœnurus cerebralis* = *Multiceps multiceps*) in that the former is always associated with purulent discharges from the nostrils, absent in the latter, and that the symptoms of the former appear during the summer, and that the latter occurs ordinarily in lambs and yearlings only (Law). There is no undue sneezing or rubbing of the nose in gid.

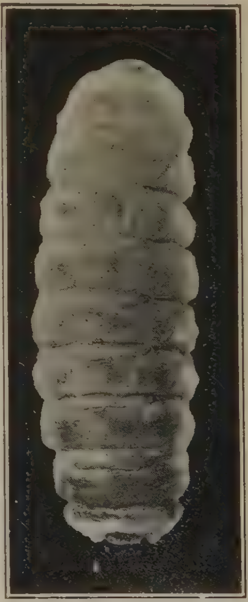

Fig. 165.—Head maggot (*Œstrus ovis*) of sheep. × 2.5.

Treatment.—Materials such as snuff, pepper, etc., may be introduced into the nostrils or sprinkled among the flock, to induce violent sneezing, which causes the expulsion of many of the larger grubs. Law recommends the injection of benzine, lifting the sheep's nose somewhat and pouring into the nostrils a teaspoonful of the remedy for each nostril. The lower nostril into which the benzine is poured is held shut for thirty seconds; the other side is then turned and the treatment repeated. The application is repeated daily or oftener until the maggots are all expelled.

Prevention.—The use of "salt logs" in sheep pastures is practiced by some sheep raisers. These logs are made by boring two-inch holes at intervals of about six inches along the length on top. Salt is placed into these holes, which are kept about half full, and in turn the edges of the holes are repeatedly smeared with pine tar, or other repellent material. In endeavoring to reach the salt the sheep involuntarily smears its nose with the substance, which protects it to a large extent against the head maggot fly.

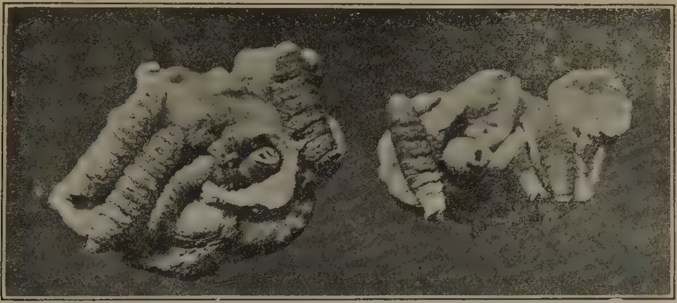

Fig. 166.—Head maggots, larvæ of *Cephenomyia sp.* attached to tissue in nasal sinuses of the deer. × .6.

d. Head Maggot of Deer and Camels

Head Maggot of Deer.—The black-tailed deer (*Odocoileus columbianus*) and other species as well are commonly affected with head maggots, a species of the genus *Cephenomyia.* The attached figure (Fig. 166) illustrates the fact that the larvæ crowd into the sinuses and that there are all sizes, from very young to fully grown, present at the same time. *Cephenomyia trompe* Linn. occurs in the reindeer of Europe, while camels of Egypt are affected by *Cephalomyia maculata* Wied.

e. Head Maggot of Horses

Head Maggot of Horses.—An important species of head maggot attacking horses in Russia and other parts of Europe and Egypt is *Rhinœstrus purpureus* Brauer. Its habits are said to be similar to those of *Œstrus ovis*. Like other species of related genera it may attack man either in the nose or eye.

f. Bots in Rodents

Bots in Rodents.—Various species of rodents, notably rabbits, rats and squirrels are infested at times with bots or perhaps we had better say, warbles (Fig. 167). Rabbits, both wild and tame, are commonly affected by *Cuterebra cuniculi* Clark, and probably other species. *C. cuniculi* is a large black and white bumblebee-like fly (Fig. 168). Just where the eggs are deposited and how the grubs reach their position under the skin is still unknown. After leaving the body of the host the larvæ pupate in 3 or 4 days, remaining in the pupal stage often for a considerable period; one case observed by the writer pupated October 25, 1912, and emerged August 12, 1913.

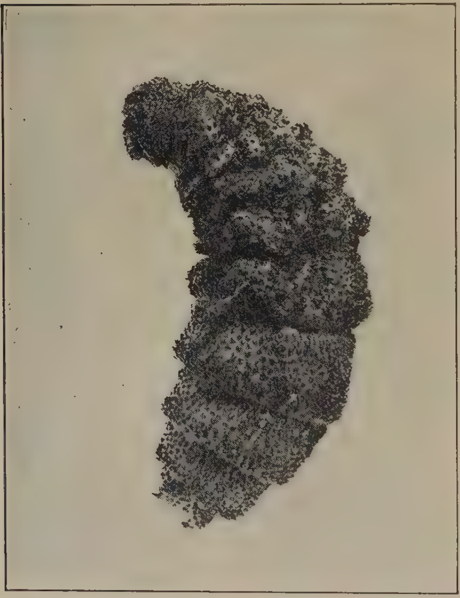

Fig. 167.—The larva of a rabbit botfly, *Cuterebra sp.* × 3.

The emasculating bot (*Cuterebra emasculator* Fitch) of squirrels is found in the grub stage in the scrotum of squirrels of several species.

g. Warbles in Humans

Warbles in Humans.—Humans, notably in Central and South America, Mexico and other tropical countries, are rather commonly affected with warbles traceable to one of several species of Œstrids, notably *Dermatobia hominis* Gmelin = *Dermatobia noxialis* Guodot = *Dermatobia cyaniventris* MacQ., *Hypoderma lineatum* Vill., and *H. bovis*, DeG.

Dermatobia hominis Gmelin[1] is commonly found in Central and South America and Mexico. The larva is known in its early stage as *Ver macaque* and in its later stages as *torcel* or *berne.* The fly measures from 14 to 16 mm. in length, is entirely brown in color. This fly parasitizes a large number of species of mammals and even birds. It has been found in cattle, pigs, dogs, mules, monkeys, man and various wild animals. In man the larva "has been reported from various regions of the body, mainly head, arm, back, abdomen, scrotum, buttocks, thigh and axilla."

Although it is not certain that this Dermatobia does not deposit its eggs directly on or in the human skin, it is now certain that several species of mosquitoes, particularly *Psorophora* (*Janthinosoma*) *lutzi* Theo., and possibly other insects act as carriers of the eggs. The female Dermatobia is said to oviposit on the undersides of the bodies of the mosquitoes so that when the latter suck blood, it is possible for the eggs to come in contact with the warm-blooded host where either contact or warmth stimulates the larvæ and rapid emergence results and entrance to the skin of the host is effected. The larval period in the body of the host is said to require about three months when, like the Hypodermas, the larvæ leave the tumorous swellings they have produced, drop to the earth and pass through a pupal period requiring from 4 to 6 weeks.

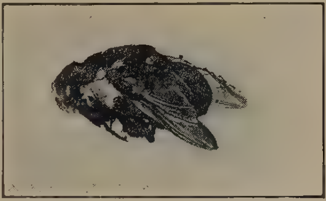

FIG. 168.—A rabbit botfly, *Cuterebra sp.* × 1.3.

Pathogenesis.—The following is quoted from Ward (*loc. cit.*):

"Dr. Brick was stung by some insect while bathing and the larva was extracted after about six weeks. It gave rise to excruciating pain at intervals, owing, as he inferred even before the determination of the cause, to 'something alive beneath the skin.' It was at first 'a considerable tumefaction over the tibia, which had the appearance of an ordinary boil (phlegmon); in the center there was a small black speck.' The tumor began to discharge at about four weeks, and was so serious that he was 'scarcely able to walk.' Scarifying the tumor yielded no results, and finally poulticing with cigar ashes and rum for five days resulted in the extraction of the larva dead. Dr. Brick records that 'it had traveled on the periosteum along the tibia for at least two inches.' While other authors hold very generally that the larva always inhabits a fixed spot in the subcutaneous tissues, I do not find that any one has referred to this record of migration made by a most competent observer."

The following observations made by Miller (Journ. Amer. Med. Assoc., Vol. LV, pp. 1978-1979) throws more light on the matter of migration, although in this case the grub was *Hypoderma lineatum.*

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[1] Ward, H. B., 1903. On the Development of *Dermatobia hominis.* Mark Anniversary Volume, Article XXV, pp. 483-512. (Includes a discussion of synonymy of species.)

"In December, 1907, the boy noticed a small round lump just below the left knee; this lump was slightly red and very tender, especially at night. About two days later the lump had disappeared from its original position and was found some three inches above the knee; the following day it was still higher in the thigh, and during successive days it appeared at different points along a course up the abdomen, under the axilla, over the scapula, up the right side of the neck, irregularly about the scalp, finally passing back of the ear and to the submental region, which it reached about two months after its first appearance; there it remained stationary. The extracted larva was identified by Doctor Stiles as *Hypoderma lineata.*"

Identification of Myiasis-producing Larvæ.[1]—The value of a simple method for the identification and classification of dipterous larvæ involved in myiasis is no doubt evident to the student of this subject. Instances are few in which the larvæ can be reared to the adult condition, when identification could of course be readily made. Authorities are now for the most part agreed that the *posterior spiracles* afford the most useful diagnostic characters, since these, while differing consistently in position, form and structure for the genera and species, show little or no variation within the species except in a few species in the very early stage immediately after hatching.

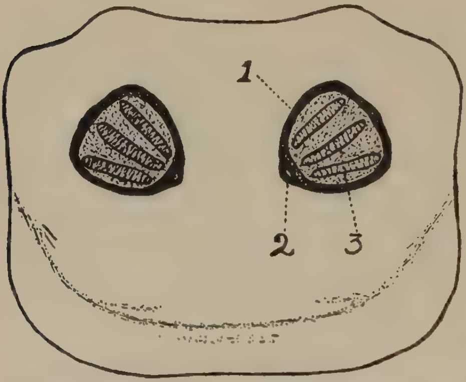

Fig. 169.—Posterior view (stigmal field) of the larva of *Calliphora vomitoria,* showing stigmal plates. (1) ring; (2) button; (3) slit-like spiracles.

To prepare the specimen for study it is necessary to first remove by means of a sharp razor the extreme posterior end (usually the broader), —a very thin section is needed. This section is then boiled until quite clear in a 2 per cent solution of potassium hydroxid (KOH), or by soaking in xylol for a few hours, after which it is prepared in the usual way for microscopic study.

It will be seen (Fig. 169) that there are two *stigmal plates* more or less separated from each other, within which are situated the *spiracles,* one to three in number, either slit-like, sinuous or more or less circular. There may or may not be present a "button," i.e., a prominence located at the narrower segment of the ring or periphery of the stigmal plate; the "button" may or may not be present in the species possessing slit-like spiracles.

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[1] Students of this subject are also referred to a splendid treatise concerning diagnostic characters of Dipterous larvæ by M. E. MacGregor published in Parasitology, Vol. VII, No. 2, pp. 176-188 with 3 plates.

In using the posterior spiracles as a basis for classification the following characters are used, i.e., (1) *diameter* of the stigmal plate, the space occupied by one stigmal plate on a line drawn through the center of both; (2) *length,* when slits are absent, the space occupied by a plate on a line drawn dorsoventrally through the center of the plate; or, when slits are present, the space occupied by a plate along a line drawn from the lower edge of button (or space if button is absent) through the longest slit (middle slit) to the margin of the plate; (3) *width,* along a line drawn at the middle of the plate at right angles to the *length* line; (4) distance between the plates; (5) general form of the plates; (6) shape of spiracles; (7) presence or absence of *button;* (8) general structure of plate.

The following key,[1] while still somewhat unsatisfactory, serves to classify the principal families of Diptera which include genera and species relating to myiasis. In this key the entire larva is needed for identification.

KEY TO THE IDENTIFICATION OF LARVÆ OF THE DIPTEROUS FAMILIES AND CERTAIN SUBGROUPS WHICH INCLUDE GENERA AND SPECIES RELATING TO MYIASIS

I. (*a*) Body cylindrical, tapering anteriorly II

(*b*) Body robust, ovate, cylindrical, rounded at the ends, slightly depressed .... *Œstridæ*
e.g., *Gastrophilus equi, Œstrus ovis, Hypoderma lineata*

(*c*) Body elliptical, much depressed dorsoventrally; segments provided with long spiny processes .... *Homalomyia*
(sub-group of Anthomyidæ)
e.g., *Fannia (Homalomyia) canicularis, Fannia (Homalomyia) scalaris*

(*d*) Body with long tail-like process .... *Eristalis*
e.g., *Eristalis tenax*

II. (*a*) With one anterior hooklet; stigmal field slightly depressed; area surrounding stigmal field usually devoid of tubercles, which if present are small and insignificant; spinose areas only on ventral surfaces of segments III

(*b*) With two anterior hooklets IV

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[1] The author is indebted to Mr. I. M. Isaacs for much careful and tedious work in the construction of this key.

III. (*a*) Posterior spiracles with sinuous slits. *Muscidæ* (except Muscina subgroup)
e.g., *Musca domestica, Stomoxys calcitrans, Hæmatobia serrata*

(*b*) Posterior spiracles with three short straight slits in each plate; few faint tubercles around stigmal field.......................... *Muscina* subgroup
e.g., *Muscina stabulans*

IV. (*a*) Spinose areas completely surrounding segment and occasionally supplementary pads on the lateral surfaces .... (1) or (2)

(1) Stigmal field depressed and surrounded by prominent tubercles; posterior spiracles with three distinct slits in each plate; plates directed more or less toward each other....................... *Sarcophagidæ*
e.g., *Calliphora vomitoria, Calliphora erythrocephala, Lucilia cæsar, Lucilia sericata, Chrysomyia macellaria, Auchmeromyia luteola*

(2) Very small (not over 4–5 mm.); anterior spiracles with few, but comparatively long lobes; posterior spiracles on end of two cylindrical processes extending posteriorly from the dorsal part of the tips of the body .... *Drosophilidæ*
e.g., *Drosophila ampelophila*

(*b*) Spinose areas on ventral and lateral surfaces; stigmal field slightly depressed and surrounded by short fleshy tubercles........ *Anthomyidæ* (except Homalomyia subgroup)
e.g., *Anthomyia radicum, Phorbia brassicæ*

(*c*) Body segments with spinose areas only on ventral surfaces; anterior spiracles with a large number (20 ±) of lobes; slightly depressed or flat stigmal field; no tubercles; posterior spiracles with three short almost parallel slits, those of one plate pointing toward those of the other; plates lacking brown chitinous borders; anal tubercles prominent, rounded and flattened........................ *Trypetidæ*
e.g., *Ceratitis capitata, Dacus oleæ*

The following species may be more or less easily identified:

Family Muscidæ

Musca domestica Linn.—Stigmal field usually slightly concave and the surrounding area devoid of distinct tubercles; stigmal plates prominent, somewhat longer than wide, D-shaped, flat sides facing, about one third diameter apart; spiracles apparently three in number and sinuous; button absent in first stage on hatching; button present thereafter, large and very dark, embedded near the center of the flattened side of stigmal plate; ring heavy and dark. (Larva of house fly.)

Stomoxys calcitrans Linn.—The stigmal field is slightly convex and is in the dorsal half of the posterior end. There are no tubercles outlining the field. The species can easily be recognized not only by the size and shape of the spiracles but by the distance between the two plates, there being from two and a half to three diameters between them. The plates themselves are small, triangular in shape and black in color. In this species each of the slits is surrounded by light areas which appear in each corner of the triangular plates. (Larva of biting stable fly.)

Hæmatobia serrata R. Desv.—The stigmal field of *H. serrata* is neither depressed nor outlined by tubercles. In shape the stigmal plates are D-shaped, as are those of *M. domestica,* but are proportionately much narrower. They are very dark in appearance, due to the fact that the black chitinous edges are joined to the comparatively large black button by three wide chitinous stripes. Portions of the sinuous slits may be seen in the small clear spaces left between the stripes. The three-part division of the surface is very similar to that found in the spiracles of *Stomoxys calcitrans.* The plates are about one fourth of their diameters apart and therefore close together compared with *Musca domestica.* In some cases there is a tendency toward a slightly triangular shape in the spiracles. (Larva of horn fly.)

Muscina stabulans Fallen.—The stigmal field is not depressed and faint tubercles may be seen dorsal to it. The spiracles are fairly prominent, almost round in shape with the inner border slightly flattened, black, with three short slits in each plate pointing toward those of the opposite plate, and from one third to one half a diameter apart. (Larva of non-biting stable fly.)

Family Sarcophagidæ

Calliphora erythrocephala Mg.—The stigmal field is slightly depressed. The stigmal plates are small and about one diameter apart. The slits in each plate converge more than do those of the other species mentioned and point almost directly toward those of the opposite plate. In the first period the plates are about as long as they are wide, occasionally being slightly wider, there being no button. In the second period they are slightly longer than they are wide, there being a prominent, bullet-shaped button, and the ring is dark and very heavy. (Bluebottle fly larva.)

Lucilia cæsar Linn.—The stigmal field is slightly depressed and is outlined by somewhat fleshy tubercles. The stigmal plates themselves are longer than they are wide and are considerably larger than are those of *C. erythrocephala.* A well-developed button is present. The ring is thin and delicate. The slits, although directed more or less toward those of the opposite plate, point more toward the ventral surface than do those of *C. erythrocephala* and do not converge as much. (Larva of the greenbottle fly.)

Lucilia sericata Mg.—The stigmal field is well depressed and is outlined by tubercles more or less conical but not very sharp. The stigmal plates are comparatively large in both the first and second period.

In the first period the plates are wider than they are long and are close together, being only about one eight of a diameter apart. The slits are long and rather narrow, pointing ventrally, those of one plate being directed in some measure toward those of the opposite plate. There is no button.

In the second period the plates are proportionately longer than in the first period and they are about one fourth of a diameter apart. The slits also are wider in proportion and although still directed ventrally they point slightly more toward those of the opposite plate. Care must be taken as to the exact meaning of length and width in this species. (Larva of sheep maggot fly.)

Chrysomyia macellaria Fabr.—The stigmal field is a very deep depression of the dorsal half of the posterior end. The depression is so deep that the lip-like edges of the last segment almost conceal the spiracles. Outlining the stigmal field are small but sharp tubercles. The stigmal plates are fairly large and are about as long as they are wide. There is no button. In the first period the plates are about one fourth of a diameter apart, while in the second period they are a little over one half of a diameter apart. The slits point ventrally, those of one plate being directed in some measure toward those of the opposite plate. (Larva of Texas screw worm fly.)

Family Anthomyidæ

Fannia (*Homalomyia*) *canicularis* Linn.—Each segment is provided with long, bristly, sharp, spiny processes. The posterior spiracles are situated on the anterior part of the last segment; they are raised, three-lobed processes. The lobes are distinct and can easily be seen. The larvæ are about 8 mm. in length when fully grown. (Larva of the lesser house fly.)

Fannia (*Homalomyia*) *scalaris* Fabr.—The processes on each segment are feathery rather than sharp or spiny and are not quite as long as the processes of *F. canicularis*. The posterior spiracles also differ in the two species, the lobes not being as well marked in *F. scalaris*. The larvæ are from 7 to 8 mm. in length when fully grown. The feathery appearance of the processes on the segments as compared to the spiny condition in *F. canicularis* is, however, most useful in distinguishing the two species. (Larva of the latrine fly.)

Family Trypetidæ

Ceratitis capitata Wied.—The stigmal field as a whole is not depressed nor is it outlined by tubercles, but occasionally each stigmal plate appears to be situated in a slight depression of its own. The plates are fairly prominent and are about twice as wide as they are long. In accordance with the group character, there is no visible chitinous edging outlining the plates. The slits of each spiracle are almost parallel and point directly toward those of the opposite plate. The spiracles differ from those of *D. oleæ* only in the distance separating the two plates, they being about one diameter apart. (Larva of Mediterranean fruit fly.)

Dacus oleæ Meig.—The appearance of the stigmal field and posterior spiracles of this species are very much like those of the previous species, except for the fact that the plates are from one and a half to two diameters apart. As in *C. capitata* there is no chitinous border outlining the spiracles, which are about twice as long as they are wide. The short straight slits of one plate point almost directly toward those of the opposite plate. (Larva of olive fly.)

Family Œstridæ

Gastrophilus equi Fabr.—One of the smallest of the Œstridæ. A full-sized larva is about 17 mm. in length and 8 mm. in width at its widest part. It is compressed, in some measure, dorsoventrally. It is wide and thick near the posterior end and tapers almost to a point anteriorly. The spines surrounding each segment are large and sharp. The two anterior hooks are prominent.

The stigmal field of this species is drawn well into the anterior position of the last segment and is completely covered and protected by a prolongation of the outer edges of this segment.

On a hard, chitinous background are six long, large, bent slits, bilaterally placed, three on either side of a small diamond-shaped hollow. (The larva of the horse botfly.)

Hypoderma lineata De G. is a large and fleshy grub and when fully developed is about 25 mm. in length and 11 mm. in width at its widest part. It is considerably depressed dorsoventrally and the segments are spinose although the large separate spines found in *Gastrophilus equi* are not present.

The stigmal field is depressed but is not covered by any prolongation of the edges of the last segment. The spiracles are large, close together and grossly granular in appearance, in some cases being more or less furrowed. A good-sized button is embedded near the inner border of each plate and in many cases a clear ungranulated stripe is found on the chitinous background between the button and the inner border. The plates usually appear to be dark brown with the button a little lighter in color. (The ox warble.)

Œstrus ovis Linn., when fully developed, is about 28 mm. in length and 8-10 mm. in width. It is, therefore, longer and narrower than *H. lineata,* a condition which gives it a more rounded appearance. The dorsoventral compression, however, is noticeable. The segments are spinose.

The stigmal field is depressed. The plates are roughly round, with the inner borders flattened. The plates are very dark, finely granular in appearance with a somewhat indistinct button in the center of each plate. (The sheep head maggot.)

CHAPTER XVII

FLEAS AND LOUSE FLIES

A. Fleas

Order Siphonaptera

Structural Characteristics.—Fleas are laterally compressed, wingless, highly chitinous, mostly leaping insects of small size, inhabiting by preference certain warm-blooded hosts and are blood-sucking in both sexes. In size the common fleas vary from 1.5 to 4 mm. in length, according to the species; there is comparatively little variation in size within a given species. The males are, as a rule, somewhat, often considerably, smaller than the females. Nearly all fleas have the ability to leap, though the Chigoe fleas, especially the females, are more or less sessile.

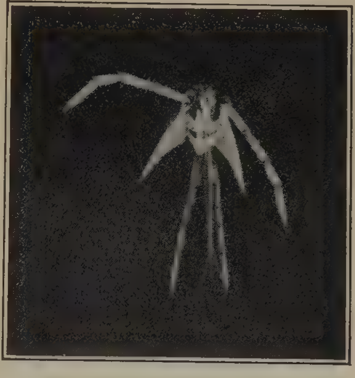
Fig. 170.—Photomicrograph of the mouth parts of a flea,—front view. (For identification of parts see next figure.)

The posterior edges of the abdominal segments are provided with backward-extending spines, which prevent backward motion through the hair of the host. There is present dorsally near the tip of the abdomen a characteristic "pincushion"-like sense organ. The piercing mouth parts (Figs. 170-171) of the adult fleas are flattened, blade-like structures consisting of a pair of triangular maxillæ with jointed palpi between which are located the organs of the proboscis, i.e., an outer pair of structures comprising the labium which ensheaths loosely the inner, more slender stylets,—a pair of mandibles with serrate edges, and a smooth labrum (hypopharynx?). On the small head are also located the sunken antennæ with annulated knobs, and the inconspicuous simple eyes (absent in some species). In some species of fleas the head is provided with rows of spines (Fig. 172), the *ctenidia*, a valuable characteristic in classification; the ctenidia may be located just above the mouth parts and are then said to be *oral,* or may be situated back of the head and are then thoracic or *pronotal* (both sets may be present).

The legs consist of five joints, viz., the *coxa* (the joint nearest the body); the *trochanter,* a very small segment between the coxa and the *femur;* the *tibia* (strongly spined), and the five-jointed *tarsus* terminating in a pair of *ungues* or claws (Fig. 172).

Life History.—The eggs of the flea (Fig. 173a) are comparatively large (.5 mm. long), glistening white and blunt at both ends. Comparatively few eggs are deposited at one laying, the observed range being from 3 to 18; however, during the entire lifetime of a female no doubt the number is quite considerable. Bacot has counted a total of 448 from a single female human flea. Most species deposit dry eggs and hence they do not become attached to the hairs of the host even though oviposition has taken place there. There is every reason to believe that some species of fleas seldom or never deposit their eggs among the hairs of the host, preferring loose earth, excrement, dust, etc. Captured fleas will readily oviposit in glass vials or other receptacles. If deposited on a dog, for example, the dry eggs fall off readily when the animal stretches and shakes itself; thus myriads of eggs may be found on the sleeping mat of a flea-infested animal.

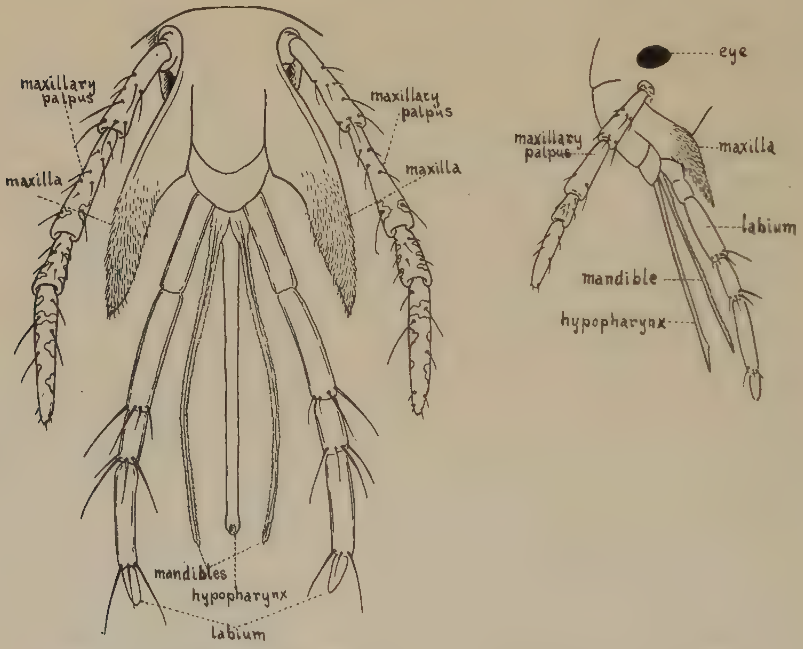

FIG. 171.—Showing mouth parts of a flea. A, front view; B, side view.

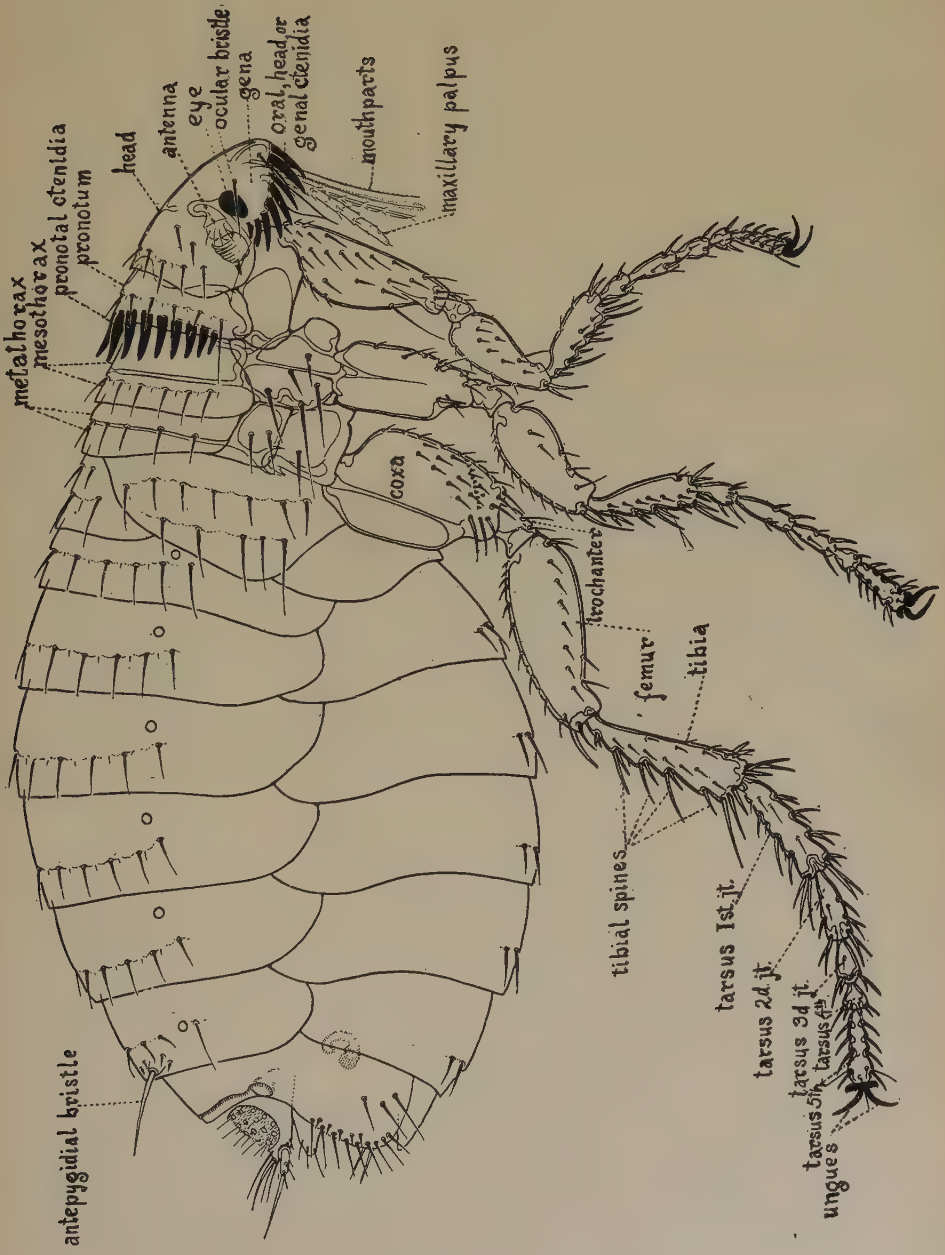

Fig. 172.—Showing principal characters used in the identification of Siphonaptera (fleas). × 45.

The length of time required for the egg stage depends largely, if not wholly, on temperature. High mean temperature from 35° C. to 37° C. inhibits development, which may account for the fact that the eggs do not hatch well on the host. At a temperature of from 17° C. to 23° C. Mitzmain[1] found that the egg stage lasted from 7 to 9 days; at from 11° C. to 15° C. it lasted about 14 days. Atlantic Coast observers have found that this stage may be passed in from 2 to 4 days.

The embryo is provided with a sharp spine on the head by means of which the egg shell is cut into shreds by a tumbling motion of its inhabitant, which is thus liberated. The larvæ (Fig. 173b) are very active, slender, 13-segmented, yellowish white maggots, with segmentally arranged bristles. The mouth parts are of the biting type and the larvæ subsist on organic matter. Very little food seems to be necessary for their development, though excrementous matter, e.g., feces from rabbits, rats, squirrels and other rodents, also dry blood, sprouting grain, etc., favor growth. The partly digested blood passing *per anum* from adult fleas appears to be necessary for the development of larvæ of some species. Excessive moisture is certainly detrimental to the life of the larvæ, although fewer fleas emerge from the cocoon during periods of hot dry weather. The larvæ are usually found in the crevices of the floor under the carpet or matting, in dusty stables, coops, kennels, nests of rodents, pig pens, etc.

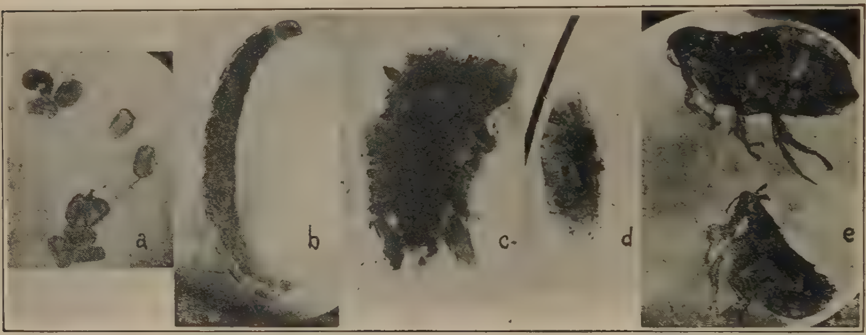

FIG. 173.—Showing life history of a rodent flea. *a*, eggs; *b*, larva; *c*, pupa in cocoon; *d*, pupa removed from cocoon; *e*, fleas,—male (lower), female (upper). × 12.

The length of the larval stage, during which there are at least two molts, is also influenced by temperature, and moisture in addition. Under laboratory conditions with room temperature this stage requires from 28 to 30 days and over, though here again other workers report from 7 to 10 days. At the end of the larval period, the insect spins a silken, whitish cocoon (Fig. 173c) in which transformation takes place. The pupa (Fig. 173d) lies within this cocoon.

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[1] Mitzmain, M. B., 1910. General observations on the bionomics of the rodent and human fleas. U. S. Public Health Service Bull. 38.

Warm, moist weather favors the metamorphosis of the pupa, from which the fully developed imago emerges in from 10 to 14 days.

Mitzmain (*loc. cit.*) observed one individual of the squirrel flea (*Ceratophyllus acutus* Bak.) from egg to imago with the following results: egg stage, 8 days; first larval stage, 6 days; second larval stage, 10 days; third larval stage, 12 days; cocoon (pupal stage), 21 days; total, 57 days.

The following table (Table XIV), after the same author, indicates the wide variation in length of life history as reported by various authorities.

TABLE XIV

TIME REQUIRED FOR THE LIFE CYCLE OF FLEAS IN DIFFERENT COUNTRIES COMPILED FROM ACCOUNTS OF VARIOUS AUTHORS (MITZMAIN)

COUNTRY AND SPECIES OF FLEA	EGG	LARVA	PUPA	COMPLETE GENERATION
India:				
L. cheopis	2 days	1 week	7 to 14 days	21 to 22 days
Australia:				
P. irritans	6 days	12 days	14 days	4 to 6 weeks
Europe:				
P. irritans	4 to 6 days	11 days	12 days	4 to 6 weeks
Ct. canis	2 weeks	12 days	10 to 16 days	5 to 6 weeks
United States:				
Atlantic Coast:				
P. irritans Ct. canis	2 to 4 days	8 to 24 days	5 to 7 days	2 to 4 weeks
Pacific Coast:				
P. irritans	7 to 9 days	28 to 32 days	30 to 34 days	9 to 10 weeks
L. cheopis	9 to 13 days	32 to 34 days	25 to 30 days	9 to 11 weeks
C. acutus	7 to 8 days	26 to 28 days	24 to 27 days	8 to 9 weeks
C. fasciatus	5 to 6 days	24 to 27 days	24 to 26 days	7 to 8 weeks

Longevity of Fleas.—It is of great importance to know how long a flea will live with and without food under various conditions. If not provided with a moist medium in which to live and at the same time deprived of the opportunity of feeding on a warm-blooded animal the majority of fleas die in about six days or less. In a moist medium such as wheat grains and sawdust (moistened), Mitzmain has kept squirrel fleas alive from 38 days in one case to 65 days in another, the former a male, and the latter a female. Rat fleas on human blood alone averaged $8\frac{1}{2}$ days (maximum 17) for the males, and $32\frac{4}{5}$ days (maximum 160) for the females.

Hosts and Occurrence of Species.—As will be seen later in this chapter, the rodent fleas are most important from the public health standpoint, and transferrence from host to host of different species is a well-known habit, adding much to the danger of disease transmission.

It is true that ordinarily a certain species of flea is found to predominate on a given species of host, for example, *Ctenocephalus canis* Curt. on the dog, *Ceratophyllus fasciatus* Bosc. on the rat in the United States, *Xenopsylla cheopis* Roth. on the rat in India, *Ctenopsylla musculi* Duges on the mouse, *Pulex irritans* Linn. on the human, etc.

For example, in an unpublished report to the writer on the species of fleas found on rats in San Francisco, Rucker states that a great preponderance of the rat fleas recovered in San Francisco are *Ceratophyllus fasciatus* as based on 10,972 specimens as follows:

Ceratophyllus fasciatus	68.07%
Xenopsylla (Læmopsylla) cheopis	21.36%
Pulex irritans	5.57%
Ctenopsylla musculi	4.48%
Ctenocephalus canis	.52%

The following tables (Tables XV and XVI) adapted after McCoy[1] throw much light on the interchange of hosts and predominance of species:

TABLE XV

FROM BROWN RATS (*Epimys norvegicus*)

NO. OF RATS COMBED	C. FASCIATUS		L. CHEOPIS		P. IRRITANS		CT. MUSCULI		CT. CANIS	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
606	570	1252	790	1146	225	425	44	137	13	15

TABLE XVI

FROM BLACK RATS (*Epimys rattus*)

NO. OF RATS COMBED	C. FASCIATUS		L. CHEOPIS		P. IRRITANS		CT. MUSCULI		CT. CANIS	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
11	7	32	6	5	0	0	4	17	0	2

TABLE XVII

FROM MICE (*Mus musculus*)

From an unknown number of *Mus musculus*

	C. FASCIATUS		L. CHEOPIS		P. IRRITANS		CT. MUSCULI		CT. CANIS	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
	1	5	2	0	0	0	3	10	0	0

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[1] McCoy, George W., 1909. Siphonaptera observed in the Plague Campaign in California, etc. U. S. Public Health Reports, Vol. 24, No. 29.

TABLE XVIII

From California Ground Squirrels (*Citellus beecheyi*)

No. of Squirrels Combed	C. acutus		Hop. anomalus	
	Male	Female	Male	Female
132	2065	2306	86	140

TABLE XIX

From the Dog (*Canis familiaris*)

No. Combed	Ct. canis		P. irritans		Ct. felis		C. acutus	
	Male	Female	Male	Female	Male	Female	Male	Female
4	10	44	8	17	0	1	1	0

TABLE XX

From the Cat (*Felis domestica*)

No. Combed	Ctenocephalus felis	
	Male	Female
2	5	15

TABLE XXI

From Man (*Homo sapiens*)

No. of Individuals	P. irritans		Ct. felis		Ct. canis		C. acutus	
	Male	Female	Male	Female	Male	Female	Male	Female
29	117	220	1	0	1	0	1	2

Light Reactions.—In a series of light reaction experiments by the writer on two species of fleas, *Pulex irritans* and *Ceratophyllus acutus*, it was found that the former reacts positively and directly to light (incandescent) at 10 C.M., 83 + C.M. and 100 C.M., and is indifferent to 7 — C.M., while the latter species reacts negatively to higher intensities, such as 46 + C.M. and 83 + C.M., and is indifferent to lower intensities such as 9 + C.M. and 7 — C.M.

The larvæ of *C. acutus* react in the main positively to light in their early stages, becoming more and more negative as they grow older. An intensity of 8.38 C.M. was used at intervals of three and five days.

Chemical Experiments.—To determine the lethal property of various chemicals, a series of experiment vials were made after the fashion of cyanide bottles for killing insects, i.e., a chamber was prepared into which cotton was placed soaked in the material to be tested and covered with dry blotting paper; the fleas thus did not come in direct contact with the chemical.

It was found that certain essential oils, such as lavender, citronella, mirbane, caraway, peppermint, eucalyptus and pennyroyal have a stupefying effect on fleas when used in strong concentrations, 50 per cent and over. It is quite probable that rubbing the body, particularly with oil of citronella, would act as a fairly good repellent.

Systematic.—Over 500 species of fleas have been described, of which number only a few need to be considered here, particularly those affecting rodents and man. The Siphonaptera (also referred to as Aphaniptera) are commonly divided into three families, viz., Sarcopsyllidæ, Pulicidæ and Ctenopsyllidæ. The following keys for the classification of fleas together with descriptions are adapted mainly after Banks.[1]

1. Thoracic segments much shortened and constricted; labial palpi apparently not jointed; third joint of antennæ without subjoints; no ctenidia; abdomen of female becomes more or less swollen *Sarcopsyllidæ*
   Thoracic segments not shortened nor constricted; labial palpi with joints; third joint of antennæ with several more or less distinct subjoints; ctenidia often present; abdomen of female never distinctly swollen 2
2. Posterior tibial spines in pairs .... *Pulicidæ*
   Posterior tibial spines mostly single and more numerous *Ctenopsyllidæ*

Family Pulicidæ

1. Head without ctenidia; eyes distinct 2
   Head and pronotum with ctenidia; last tarsal joint with four pairs of lateral spines 5
2. Pronotum without ctenidia 4
   Pronotum with ctenidia 3
3. Female with one antepygidial bristle on each side .... *Hoplopsyllus*
   Last tarsal joint with five pairs of lateral spines; female with two to five antepygidial bristles each side .... *Ceratophyllus*
4. Mesosternite very narrow, without internal rod-like incrassation from the insection of coxa upward .... *Pulex*
   Mesosternite with a rod-like internal incrassation from insection of coxa upward .... *Xenopsylla*
5. Eyes rudimentary; female with two to five antepygidial bristles each side .... *Neopsylla*
   Eyes distinct; female with one antepygidial bristle each side *Ctenocephalus*

Family Sarcopsyllidæ

"The fleas of this family are commonly called 'chigoes,' 'jiggers' or sand fleas. The head is usually larger proportionately than in other

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[1] Banks, Nathan, 1910. The ectoparasites of the rat. A symposium on "The Rat and its Relation to the Public Health." U. S. Pub. Health Service Bull., Washington, D. C.

fleas; there are no ctenidia on head or pronotum; the thoracic segments are extremely short, and in the female the abdomen enlarges with the development of the eggs. They do not hop about as other fleas, but remain on the spot to which they have attached themselves, until they die. Frequently the adjacent skin grows over them, forming a swelling of considerable size."

1. Angle of head acutely produced; fifth tarsal joint of hind legs without heavy spines; few spines on the legs....................*Sarcopsylla*
   Angle of head not produced, obtuse; fifth tarsal joint with heavy lateral spines and other spines on other parts of the legs......*Echidnophaga*

Family Ctenopsyllidæ

"To this family belongs the *Ctenopsylla musculi* Duges (Fig. 174). "This was formerly placed in the genus *Typhlopsylla*. The head is rather acute in front and has four ctenidia each side; the eyes are very small; the pronotal comb has 22 spines; each dorsal segment of the body has two rows of hairs; the basal row of smaller hairs. The proportions of joints in the hind tarsus are: 45-25-17-8-14. Length 1.8 to 2.5 mm. This species is abundant on rats and mice in Europe and other countries; recently it has been taken in California and Florida on rats and mice."

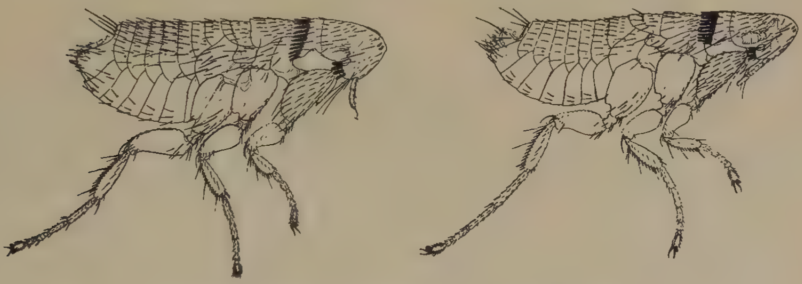

FIG. 174.—*Ctenopsylla musculi,* a mouse flea; male, right; female, left. × 17.

THE COMMONER SPECIES

Pulex irritans Linn. (Fig. 175).—"The mandibles reach about halfway down on the anterior coxæ; the head is regularly rounded in front; two bristles on the gena, one placed low down just above the maxilla, the other below the eye; there are no transverse rows of bristles on the vertex, and but one row of bristles on each abdominal tergite The proportions of the joints of the hind tarsus are: 5-30-18-12-32. Color, usually yellow-brown. Male, 1.6 to 2 mm.; female, 2 to 3.5 mm.

"This, the human flea, is quite cosmopolitan, but more abundant in warm countries than elsewhere. It occurs on many domestic animals and has frequently been taken from rats in California and elsewhere; it also occurs on skunks." Swine are often badly infested with this species.

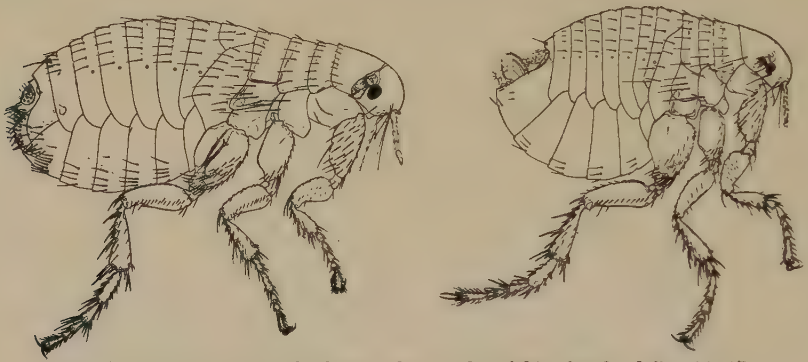

FIG. 175.—*Pulex irritans,* the human flea; male, right; female, left. × 17.

Ctenocephalus canis and *felis* (Fig. 176).—"The common fleas on cats and dogs, as well as on man, belong to two species long kept under one name (*C. canis* or *C. serraticeps*), but lately shown by Rothschild to be distinct. Both have a comb of eight spines on the head and sixteen spines in pronotal comb; the proportions of joints in the hind tarsus are: 40-24-15-10-24. They may be separated as follows:

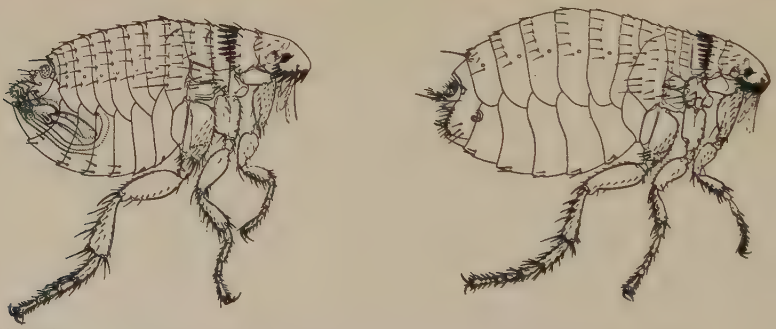

FIG. 176.—*Ctenocephalus canis,* the cat and dog flea; male, left; female, right. × 17.

1. In the female the head is fully twice as long as high (seen from side); the first spine of genal comb is two thirds the length of the second; in male the manubrium of claspers is barely enlarged at tip; and with two rows of hairs on disk of movable finger......*C. felis* Bouché

In the female the head is less than twice as long as high (seen from side); the first genal spine in the head comb is only about one half the length of the second; in the male the manubrium of clasper is very distinctly enlarged at tip; but one row of hairs on the disk of the movable finger..............................*C. canis* Curtis

Ceratophyllus fasciatus Bosc. (Fig. 177).—"There are eighteen or twenty spines in the pronotal comb; there are three bristles in front of eye and in female two, and in male four in front of these; there are three or four hairs on the inner surface of the hind femur; the proportions of joints in the hind tarsus are: 50-33-20-11-21. The manubrium of the male claspers is very long and slender, and some of the bristles on the movable finger are as long as the joint. Length, male, 1.8 mm.; female, 2.5 mm.

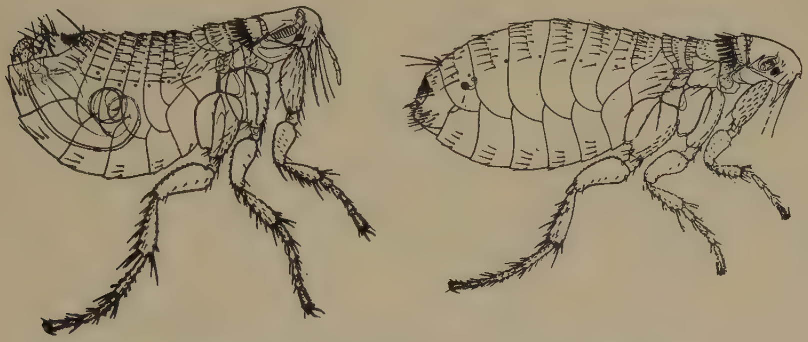

FIG. 177.—*Ceratophyllus fasciatus*, the rat flea; male, left; female, right. × 17.

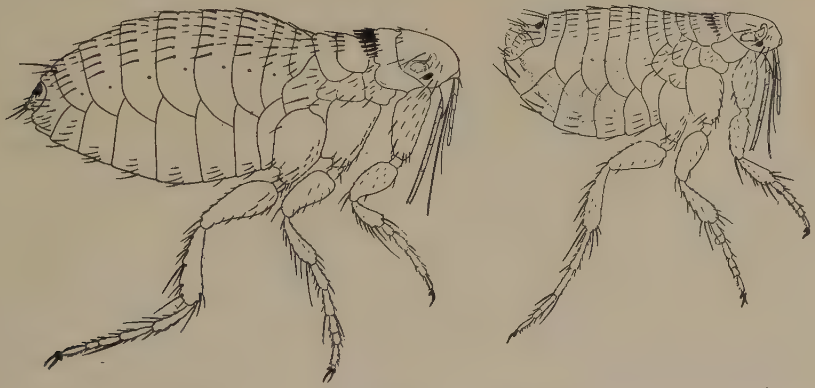

FIG. 178.—*Ceratophyllus acutus*, the squirrel flea; male, right; female, left. × 17.

"It has been recorded in California on rats, mice, skunks and man. It is also common in Europe and elsewhere on rats, mice and other small animals."

Ceratophyllus acutus Baker (the squirrel flea) (Fig. 178).—"This species is readily known by having a spine at tip of the second joint of hind tarsus longer than the third joint and reaching over on to the fourth joint; the abdominal tergites have each two rows of bristles;

the male claspers are very large and long, sickle shaped. Color, pale brown. Length, 3 to 3.5 mm."

Ceratophyllus niger Fox.—"This species has the pronotal ctenidia of about 26 spines; there are a few hairs on the inner surface of hind femur; apical spines of second joint of hind tarsus not longer than third joint; three hairs in front of the eye and three in front of these; movable finger of claspers with five slender bristles on the outer edge. Color, very dark brown. Length, 3.5 mm.

"Taken in California from *Epimys decumanus* and from man."

Ceratophyllus londinensis, Rothsc.—"This species is closely allied to *C. fasciatus,* and best separated from it by the shape and armature of the genital parts; the manubrium is not as long as in that species, and the bristles on the movable finger are shorter; the third joint of the maxillary palpi is proportionately longer than in *C. fasciatus.* There are three bristles in front of the eyes and four or five in front of these; there are a few hairs on the inner surface of the hind femur; the proportions of the joints in the hind tarsus are: 46-30-18-11-18.

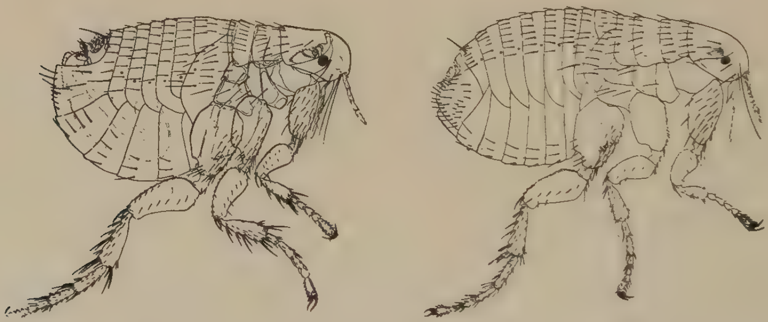

FIG. 179.—*Xenopsylla cheopis,* the oriental rat flea; male, left; female, right. × 17.

"It has been recorded by Dr. Fox from *Epimys rattus* in California, and is known from rats and mice from several parts of Europe."

Xenopsylla cheopis Rothsc. (Fig. 179).—"The mandibles reach nearly to the end of the anterior coxæ; there are no ctenidia on the head or pronotum; two bristles on gena; oral bristles placed low down just above the base of the maxilla; ocular bristle in front and just above the middle of the eye; the eyes are distinct; each abdominal tergite has but one row of bristles; the hind femur has a row of about eight bristles; the proportions of the joints in the hind tarsus are as follows: 40-30-16-10-20. Color, light brown. Male, 1.5 to 2.0 mm.; female, 2 to 3.0 mm."

"This is a true rat flea, but will readily bite man, and is the species chiefly concerned in transmitting the bubonic plague. It is widely distributed, especially in seaport towns."

Hoplopsyllus anomalus Baker.—"The mandibles scarcely reach halfway down on the anterior coxæ; upon each are two large spines; the pronotal comb has about nine spines each side; and each abdominal segment has but a single row of bristles. The hind femora have six to eight bristles on the side; the proportions of the joints in the hind tarsus are: 26-16-8-5-13. Color, dark reddish brown. Female, 2.5 mm.; male, 1.5 mm.

"Described from a spermopile from Colorado and recorded by Dr. Fox and Professor Doane from *Epimys norvegicus* from California."

Echidnophaga gallinaceus Westw.—"This species has the body almost as broad as long, and of a red-brown color; one bristle in front of eye and six on each metathoracic pleuron; each abdominal tergite has on each side near the median line a single hair; the spiracles are situated well down on the sides. Length: male, 0.8 to 1.2 mm.; female, 1 to 1.8 mm.

"This species is a fairly common pest of poultry and dogs in warm countries, and is called the 'chicken flea,' or 'stick tight.'"

Dermatophilus (*Sarcopsylla*) *penetrans* (Linn.).—This species differs from the above in that the eyes and antennæ are situated in the anterior half of the head, and the metathoracic scales are rounded.

Plague.—Plague is a bacterial disease traceable to *Bacillus pestis*, runs a rapid course, presents a high mortality, 20 per cent to 95 per cent, depending upon hygienic and social conditions, and while it has appeared in devastating epidemics in temperate climates, it is endemic in certain warmer countries, particularly southern India and China.

Three forms of the disease may be considered; namely, *bubonic, septicemic* and *pneumonic.* The incubation period varies from two to eight days ordinarily, according to Manson, though longer and shorter periods have been observed. In the bubonic plague, which constitutes by far the greater percentage of the cases, there appear characteristic swellings (buboes) in the groin (femoral glands), axilla (axillary glands) or other parts. These buboes vary from 2 cm. to 10 cm. in diameter; these appear within a day or two. In septicemic plague the bacilli appear in the blood in large numbers, there is a comparative absence of swellings, the disease is very virulent and runs a very rapid course, terminating in death in from one to three days.

In pneumonic plague the seat of the disease is the lungs. This form is considered most dangerous and is most infectious.

The plague bacillus was discovered concomitantly and independently by Kitasato and Yersin in 1894, when it became established that rat plague and human plague were identical. Epidemics of plague in humans have evidently always been announced by fatal epizoötics among rats.

Plague Transmission.—Many theories have been advanced to account for the transmission of plague, notably soil and climatic conditions, but apparently insects were not suspected until the latter part of the last century. Nuttall[1] in 1897 demonstrated the presence of *B. pestis* in the bodies of bedbugs (*Cimex lectularius*) which had fed on the bodies of rats sick of plague. Simond[2] in 1898 first succeeded in transmitting plague from a sick rat to a healthy rat through the agency of infected fleas. Simond's work was discredited for a number of years, but was successfully repeated by Verjbitski[3] in 1903.

Liston[4] in 1904, working in Bombay, came to the following conclusions: (1) There was one flea infecting rats in India far more commonly than did any other, viz., *Xenopsylla* (*Pulex*) *cheopis* Rothsc.; (2) that these fleas when feeding on a plague rat harbored the plague bacillus in their bodies and that it multiplied therein; (3) that where fatal plague occurred many of these infected fleas were at large, and (4) that after a local epizoötic of rat plague, man was also found to harbor these rat fleas and might become infected as had the guinea-pigs used in the experiment.

The following is a summary of experiments conducted by the Indian Plague Commission before and after its organization in 1905.

In the first instance healthy rats were confined in close proximity to rats which, inoculated with plague, had succumbed to that disease, and that previous to this had been artificially infected with rat fleas (*X. cheopis*). The separate confinement of the rats in each case was so arranged that both contact with and access to all excreta were excluded, although it was provided that the fleas could pass from the inoculated to the healthy rats; this transfer actually did take place and in many cases these fleas contained virulent plague bacilli; and when healthy non-immune rats were thus infected they died of plague to the extent of 79 per cent; this extent of infection fell to 38 per cent, when partly immune rats of local origin were employed.

That the plague had originated in the healthy rats through the intermediary of the rat fleas was further demonstrated by the fact that when they were actually transferred from artificially plague-infected to healthy English rats, the disease resulted to the extent of 61 per cent.

Further, on constructing a series of miniature houses (godowns) so as to reproduce the conditions pertaining to ordinary domiciles, it was found that whenever these were so constructed as to admit rats to their roofs, but not to their interiors, guinea-pigs confined therein became successively infested by rat fleas and infected by plague, but that in those houses to which rats could not gain access plague was originated in guinea-pigs living therein, either by transferring rat fleas to them, derived from plague-infected guinea-pigs, or on accidental admission of rat fleas from other sources. Also, that when so confined, guinea-pigs had, under these conditions, died of plague; healthy flea-free guinea-pigs, subsequently introduced, became plague smitten, and that the contagion remained in the place in proportion as the test animals were accessible to, and were found to be infested with, fleas. In other words, that "if the fleas be present, the rate of progress being in direct proportion to the number of fleas present." Further, that when in one of the houses, to the interior of whose roof fleas could not gain access, healthy guinea-pigs were confined, guinea-pigs became flea infested and infected when running on the ground, to a less extent when the cage was placed two inches therefrom, and not at all when it was suspended two feet above it. The fact that infection took place where rats were located two inches above the ground indicates that contact with infected soil is not necessary for plague to originate, and that "an epizoötic of plague might start without direct contact of healthy with infected animals."

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[1] Nuttall, G. H. F., 1897. *Loc. cit.*

[2] Simond, P.—L. S., 1898. La propagation de la peste. Ann. de l'Inst. Pasteur, Vol. XII, p. 625.

[3] Verjbitski, D. T., 1908. The part played by insects in the epidemiology of plague. Journ. of Hyg., Vol. VIII, p. 162.

[4] Liston, W. G., 1905. Plague rats and fleas. Journ. Bombay Nat. Hist. Soc., Vol. XVI, pp. 253-273.

To demonstrate that this communication of plague from guinea-pig to guinea-pig was through the intermediary of fleas, rat fleas were taken from a morbid guinea-pig and allowed to feed through muslin on healthy animals. The positive outcome of this experiment proved the above statement.

The state of affairs that existed in actual domiciles in which plague occurred or had existed was next inquired into, advantage being taken of the fact that plague-susceptible guinea-pigs would serve as hosts for, and for the collection of, fleas.

Guinea-pigs free from fleas were introduced into rooms in which persons had died of plague, or from which plague-infested rats had been taken. They were allowed to be at large in these rooms for periods of from eighteen to twenty-four hours. These guinea-pigs not only collected the fleas on their bodies, most of which were rat fleas, but 29 per cent of them contracted plague and died of plague within a few days after being restored to ordinary confinement. As before, many of the fleas which they yielded harbored plague bacilli in their stomachs, and were capable of infecting additional animals.

Further, after first washing the floors and walls of the rooms with an acid solution of perchlorid of mercury, and so adequately disinfecting them for plague, but not for fleas, and then introducing guinea-pigs, these latter became plague-infected if rat fleas were present.

That the infection was actually due to fleas was also shown by the positive results from fleas collected from rats occurring in plague-infected houses and transferring them to healthy rats or guinea-pigs in the laboratory. These in due course became infected and died of plague.

Similarly fleas taken from the clean guinea-pigs allowed to run in plague-infected houses, and transferred to fresh animals, communicated plague to them in eight out of forty experiments.

In the next place, plague-free white rats, guinea-pigs and monkeys were placed in enclosures, which precluded contact as well as soil infection, in plague-infested rooms, pairs of one animal or another being used in each of the forty-two experiments of this class conducted, one individual being confined to a flea-proof receptacle and the other to an adjacent one accessible to these insects (one animal being thus a control). In the latter case plague resulted in four instances, or 10 per cent gave positive results.

As a variation of the same experiments, the enclosures for individual animals, whilst protected from soil or contact infection, were surrounded, as a screen to fleas, by 2½ inches of "tanglefoot" or were unprovided with this protection, the "tanglefoot" being replaced by sand. (Twenty-nine experiments were conducted.) In the latter case the animals became infested with fleas, one having as many as twenty; seven became fatally infected with plague. In the former, individual fleas were only found on three of the rats and no animals became plague-infected.

Examining the fleas entrapped, 247 in number, it was found that 147 were human fleas, 84 were rat fleas, and 16 cat fleas. Moreover, a large proportion of each kind was examined. No plague bacilli were found in the cat fleas, 1 only in 85 of the human fleas was infected, and no less than 23 out of 77 of the rat fleas harbored plague organisms.

It was also shown that, when rats in the course of an epizoötic died of plague, the pathological features manifested in their bodies corresponded to those exhibited by artifically rat-flea-infected animals, and hence it was inferred that in nature and under experimental conditions the animals had alike succumbed to a single agency. This identity especially related to the site in which buboes arose, that in both instances, where the place of inoculation could be observed was similar.

Further Observations.—A study of mortality statistics shows that the greater percentage of plague occurs in the autumn,—September and October. This seasonal occurrence is undoubtedly due to climatic conditions, moisture and cold as affecting the life history and habitat of the rat and of the flea. Blue[1] reports a number of observations made in San Francisco indicating modes of infection; thus two small boys found the body of a dead rat in an unused cellar; the rat was buried with unusual funeral honors and in forty-eight hours both were taken ill with bubonic plague. Again, a laborer picked up a dead rat with the naked hand and threw it into the bay. He was taken ill with plague three days later. The case of a physician's family is also cited in which foul odors pervaded their second story flat over a grocery store. On removing the wainscoting around the plumbing to ascertain the cause of the odor, two rat cadavers were found in the hollow wall. In two or three days thereafter the two members of the family who used the room sickened, one dying on the fifth day of cervical bubonic plague. Blue believes that the removal of the wainscoting set free infected rat fleas.

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[1] Blue, Surgeon Rupert, 1910. Rodents in relation to the transmission of plague. U. S. Pub. Health Bulletin. The rat and its relation to the public health.

A most illuminating case is reported in the U. S. Public Health Reports (Nov. 7, 1913, p. 2356), viz., a fatal case of plague occurred in Manila (P. I.) in the person of an American, editor of the Manila Daily Bulletin. A plague rat had been found on September 6 in the block adjacent to the one in which the newspaper offices were located. The editor was admitted to the hospital September 19 and died at the Plague Hospital three days later. A mummified rat was found in the desk of the late editor, together with live fleas, *Xenopsylla cheopis*. Both the fleas and rat revealed bipolar staining organisms and inoculations into healthy laboratory rats produced typical cases of plague terminating fatally.

The facts that the mummified rat must have been dead at least two weeks and that the live fleas contained plague bacilli causes the comment to be made that "these facts furnish strong proof that plague might be introduced into a country without either the importation of human or rat cases of plague and that fleas might be alone concerned."

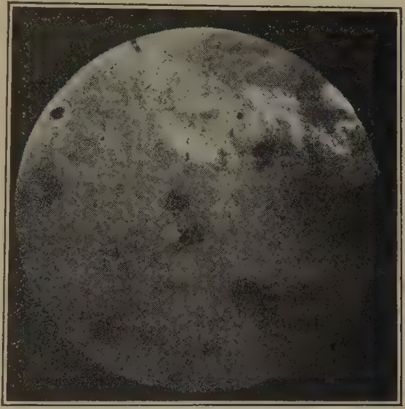

FIG. 180.—Showing ***Bacillus pestis*** from the intestine of a rat flea, ***Ceratophyllus fasciatus***, taken from a plague rat. (Photograph by Mitzmain. Greatly enlarged.)

How the Flea Receives and Transmits Plague.—It was found by the Indian Plague Commission according to Fox (*loc. cit.*), that the average capacity of a flea's stomach (*Xenopsylla cheopis*) was .5 cubic millimeter and that it might receive as many as 5,000 germs while imbibing blood from a plague rat. They further found that the bacilli would multiply in the stomach of a flea (Fig. 180) and that the percentage of fleas with bacilli in the stomach varied with the season of the year. In the epidemic season the percentage was greatest for the first 4 days, and on one occasion the stomach was found filled with *Bacillus pestis* on the 20th day. In the non-epidemic season no plague bacilli were found in the stomach after the 7th day. They also found that in the epidemic season fleas might remain infective up to 15 days, while in the non-epidemic season but 7 days, and in the latter case the percentage of infection in animals was much less than in the epidemic season. They showed that while one flea was occasionally able to carry the infection this was not usual. It was found that both males and females were capable of transmitting the disease. As to the manner of dissemination the Commission found bacilli only in the stomach and rectum and never in the salivary glands nor body cavity and but rarely in the esophagus, and then only when the flea was killed immediately after feeding. As far as the writer knows the plague bacilli have not been demonstrated on the mandibles, hence this fact and the absence of the bacilli from the salivary glands seems to preclude the possibility of direct inoculation by the bite, although it seems quite probable that plague bacilli might be regurgitated, particularly when the flea's stomach is overfull or plugged and thus be injected at the time of biting. Very recently Bacot and Martin[1] have come to the conclusion that plague can be transmitted during the act of biting when a temporary blocking or obstruction of the proventriculus takes place through a multiplication of the organisms causing bacillus-laden matter to be forced forward or regurgitated into the wound by the pumping valves, thus producing infection.

It will be observed that when a flea bites it commonly ejects feces and partially digested blood in the vicinity of the bite. It has been shown that an emulsion of plague flea feces placed upon the wound produced by the bite induces the disease in the animal, provided this is done within 24 hours after the insect has bitten, after which time the wound has probably healed sufficiently to exclude the organisms. The actual inoculation is, therefore, evidently an accidental process, i.e., the plague bacilli discharged *per anum* are *rubbed* into the bite of the flea either by the insect as it moves about or by the person in the act of scratching,—many persons very commonly scratch a flea bite until it bleeds. This method, together with that advanced by Bacot and Martin, probably explains the flea's rôle in the dissemination of plague.

Squirrels and Plague.—Plague has been found in a number of species of rodents other than rats, notably ground squirrels (*Citellus beecheyi*) (Fig. 181). In California the disease was demonstrated in ground squirrels under natural conditions in 1908 according to McCoy.[2] According to this author at the time of his writing (1910), about a dozen persons had contracted the disease under circumstances that pointed conclusively to squirrels as the cause. The two species of fleas commonly infesting the ground squirrel in California are *Ceratophyllus acutus* Baker and *Hoplopsyllus anomalus* Baker of which the former is far more numerous. McCoy proved the first-named species a carrier as follows. He inoculated a ground squirrel subcutaneously with a broth culture of *B. pestis* derived from a human case of plague. This squirrel died on the fifth day, but three days before its death, 100 fleas, *C. acutus*, were put in the cage with it. The dead animal was removed from the cage while warm, and 27 live fleas taken from its body. Smears made of the crushed bodies of two of these fleas showed an abundance of pest-like bacilli in each. The remaining 25 fleas were put into a clean cage with a healthy squirrel. This animal died of subacute plague 10 days later, the buboes being in the region of the median, posterior inguinal and pelvic glands. A pure culture of *B. pestis* was obtained from the liver. McCoy states that the experiment is conclusive in showing that *C. acutus* may convey plague from a sick to a healthy squirrel. The squirrels used in the experiment were kept in quarantine for at least a month prior to their being used, which was necessary to exclude any naturally infected ones. McCoy found the bacilli in squirrel flea feces 4 days after removal of the fleas from the host.

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[1] Bacot, A. W., and Martin, C. J., 1914. Observations on the mechanism of the transmission of plague by fleas. Journ. of Hygiene. Plague Supplement III, Jan. 14, 1914, pp. 423-439.

[2] McCoy, George W., 1910. Bubonic plague in ground squirrels. N. Y. Med. Journ., Oct. 1, 1910; see also U. S. Public Health Bulletin, No. 43.

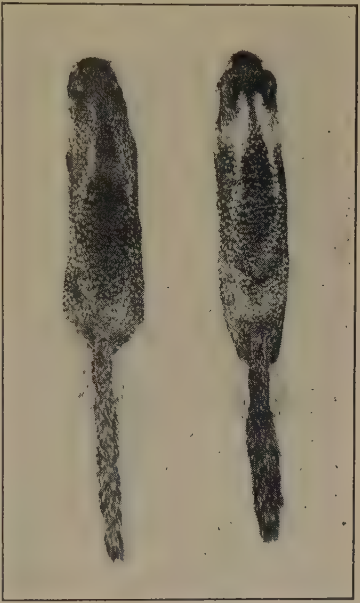

Fig. 181.—Two varieties of the common "digger" ground squirrel of the Pacific Coast. The squirrel at left is the Douglas ground squirrel (*Citellus douglasi*), found along the coast north of San Francisco Bay; the one to the right is the California ground squirrel (*Citellus beecheyi beecheyi*), the common ground squirrel of the interior valleys and a carrier of bubonic plague. (Photo by University of California Museum of Vertebrate Zoology.) × .16.

Flea Control.—(*A*) *Fleas in the House.*—The commonest household flea in Europe is *Pulex irritans*, the human flea, also predominating in California, while *Ctenocephalus canis*, the cat and dog flea, is commonest in the eastern portion of the United States. Both species are very often present at the same time, and both species infest cats and dogs; as a matter of fact they have a wide range of host animals. Unless house dogs and cats are very carefully groomed and repeatedly washed or dusted with efficient insecticides the presence of these animals will always be a source of many fleas.

In treating a house for fleas it must be borne in mind that the larvæ develop primarily in the crevices of the floors, under carpets and mattings. The old-fashioned tacked-down carpets and mattings, still so commonly used, must be done away with, unless an insecticide is used, which when applied to carpets in wetting quantities does not injure the fabric. Benzine is often recommended, but its dangers must be considered, both before and after applying. The writer does not undertake the responsibility of recommending benzine for this purpose. With the removal of carpets and matting, floors can easily be moistened with an oil mop, using kerosene. All parts of the floor in all parts of the house must be reached. The odor of kerosene is not particularly disagreeable and at all events soon disappears. Treatment should be repeated at least once every three or four weeks during the flea season. This method of treatment has invariably given good results. Dr. L. O. Howard recommends a free sprinkling of pyrethrum powder as the easiest remedy to be applied, or washing the floors with hot soapsuds. Dr. Henry Skinner has successfully destroyed fleas in a badly infested room by sprinkling the floor liberally with about five pounds of flake naphthalene and closing the room for twenty-four hours. The acrid fumes destroyed the fleas and inflicted no material injury (Felt).[1]

(*B*) *Treatment of dogs, cats and other domesticated animals* kept in or near the house is essential to the control of fleas. Mats on which house pets sleep should be shaken out over kerosene, soapsuds or a fire every few days in order to destroy flea eggs which have fallen from the host when it shakes itself. The sleeping quarters should be liberally dusted with California buhach or pyrethrum powder. Fleas also breed abundantly in loose dry manure and débris in stables, chicken houses, yards, etc. A spray of high flash point fuel oil is very useful under these circumstances. The best method to keep cats, dogs, monkeys, etc., free from fleas is to give them frequent baths with warm water to which enough creolin is added to make a 2 per cent solution. If the animal is dipped in the solution, the eyes should be quickly rinsed or sponged with clear water. The use of crude oil in hog wallows and about the pens gives good results.

Animals infested with fleas may also be liberally dusted with California buhach or pyrethrum powder. The dust rubbed well into the hair causes the fleas to drop off in a stupefied condition, when they can be brushed up and burned. If the latter is not done the insects soon revive and go about their "business" as usual. The use of powdered derris root applied lightly as a dust to the animal's coat has been found very effective as a flea powder.

(*C*) *Rat Control.*—Not only are rats an object of control because of their menace to health, but they are also injurious in many other ways. According to Lantz[2] there are several species of house rats (Fig. 182), among them the black rat (*Epimys rattus*), the roof rat

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[1] Felt, E. P., 1909. Control of household insects. Museum Bull. 129. N. Y. State Museum, Albany, N. Y.

[2] Lantz, David E., 1909. How to destroy rats. U. S. Dept. of Agric., Farmers' Bull. No. 369.

(*Epimys alexandrinus*) and the brown rat (*Epimys norvegicus*), of which the last named species is by far the commonest. All of these species were imported from the Old World. The habits of house rats, except the roof rat, are generally quite similar, hence methods of control are alike applicable, and manifestly the control of the host involves the control of the flea. Rucker [1] has well said,

> "Rodent extermination is a problem with difficulties arising from the animal's highly developed regard for self-preservation. In the main, the rat requires two conditions for life. He needs plentiful food and places suitable for nesting and breeding. Eliminate either of these elements and you drive away your rats. Yet the problem remains far more difficult than shown in the simple terms of the above equation. The fabulous speed at which rats multiply will baffle all but the most determined and efficient efforts to exterminate them. Under normal conditions each female bears three litters a year and each litter produces ten young. Under conditions ideally favorable it has been computed that one pair of rats will, in five years, provided all can live so long, increase to 940,369,969,152. Such a result is, of course, impossible in nature. . . . The size and frequency of rodent litters decreases proportionately with every cutting off of food supplies. Separate the rat from his pabulum and he will not breed so freely nor so often as when he is well fed. Destroy rat habitations and make it impossible for them to find new nesting places, and breeding will virtually cease, since the unsheltered progeny can no longer survive, and since the starving rats are driven to cannibalism in the struggle for existence."

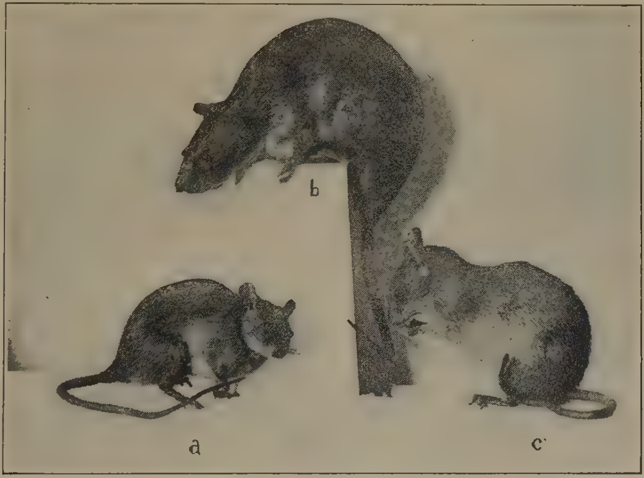

FIG. 182.—House rats. (*a*) *Epimys rattus,* the black rat; (*b*) *Epimys norvegicus,* the brown rat; (*c*) *Epimys alexandrinus,* the roof rat. × .13.

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[1] Rucker, William Colby, 1910. "Rodent extermination" in U. S. Public Health Bull. on "The rat and its relation to the public health," pp. 153-162.

Rat control may be accomplished by the proper combination of the following methods depending upon circumstances. (*a*) *Rat proofing* is by far the most important method. This is done by the use of concrete in building foundations and floors to stables, corncribs, poultry houses, outbuildings, dwellings, etc. Cement construction requires comparatively little skill, is not expensive and is becoming an important factor in building the rat out of existence. (*b*) *Cutting off the food supply* essentially means (1) proper disposal of garbage, i.e., by burning the same speedily or placing it in covered metal garbage cans; (2) cremation of slaughter house refuse; (3) use of heavy wire netting for the protection of foodstuffs, feed bins, etc. (*c*) *Natural enemies* of the rat where otherwise not objectionable should be protected. Among the hawks, the red-tailed species (*Buteo borealis*) is said to be most efficient; among the owls, the barn owl (*Aluco pratincola*) is of greater importance; skunks and weasels are good ratters; a well-trained fox terrier is a very useful adjunct to every farm. (*d*) *Rat trapping* is best accomplished by means of the snap traps. These should be well smoked and baited with fried bacon securely tied to the trigger. Each time before using, it is well to scald the trap with hot water and "sizzle" the bait with a lighted match or torch. (*e*) *Rat poisoning* is ordinarily dangerous to the life of domesticated animals and children. Among the poisons commonly used are (1) *phosphorus paste* prepared by mixing crude phosphorus over heat with glucose, cheese, meat, etc. Danger from combustion must be borne in mind. (2) *Arsenic paste* consists of an arsenious acid (powdered white arsenic) combined with oatmeal, cheese, toast, etc. (3) *Strychnin crystals* (strychnin sulphate) may be placed in pieces of cheese or meat and put in rat runways. (4) *Barium carbonate* one part to eight parts of oatmeal mixed with water into a stiff dough and placed in rat runways. *Extreme caution must be exercised in the use of rat poisons owing to danger to human life. State laws must be regarded in this respect as well.*

(*D*) *Squirrel Control.*—The most destructive as well as most dangerous species (as referred to public health) are the "digger" ground squirrels of the genus *Citellus* (Fig. 181). These squirrels live in colonies, ordinarily, and dig an extensive meshwork of connecting burrows. Their food consists of grain, seeds and fruit and is stored for the winter. The young are usually born in March and April in California and their litters number from five to ten. Three general methods of control are commonly employed. (1) Shooting and trapping. Shot guns carrying No. 7 or 8 shot are best employed, and chain traps are the best if trapping is to be done at all. (2) *Suffocation in the burrows* may be accomplished by either flooding with water or by the introduction of poisonous gases. Carbon bisulphid is the most efficient agent and is commonly employed. The following account of this gas and its use is based largely on the work of Simpson.[1]

Carbon bisulphid is obtained commercially in the form of a liquid, which is readily vaporized or is converted chemically into other gases. While it is the most useful material as applied against ground squirrels there are some objectionable features, namely, it is very inflammable, must be kept in tightly closed containers and under certain conditions may explode; furthermore, during the dry season if "exploded" in the burrow there is danger of igniting dry grass or other inflammable material in the vicinity. If handled with as much care as gasoline, for example, the danger is not so great after all. The advantages in its use are, that it is readily converted into a poisonous gas, diffuses quickly, destroys life rapidly and can be used most readily during the rainy season when green food is abundant, thus preventing the most successful use of poisoned grain.

The bisulphid may be used in one of two ways, namely, in the simple liquid condition by evaporation, when there will be but little waste, or it may be used by igniting or exploding it. In either case it is suggested that from one to three days prior to the application of the poison all squirrel burrows in the area to be treated should be stopped with earth. The holes found opened indicate the burrow in which there are squirrels.

The method of applying the bisulphid by the ignition method is as follows: To handle a large area to best advantage two men working together is suggested. "One man is provided with a supply of 'waste,' 'sacking,' or other absorbent material, divided into a number of small balls about half the size of the fist. The bisulphid is carried in an ordinary one gallon oil can, and refilled from time to time from a supply kept in a cool place out of the sun. He is supplied with matches. His 'pardner' carries a mattock or long-handled shovel. On arrival at an opened squirrel burrow, a ball of 'waste' is saturated with two ounces of bisulphid, dropped deeply in the burrow and then a match applied. After a moment's time the man with the shovel stops with earth this burrow and all other burrows near from which the gas escapes. On subsequent inspection of the field all opened burrows will indicate holes lacking effective treatment." Exploding the bisulphid thus causes considerable gas to escape, but "the ignition produces a violent chemical reaction and as a result sufficient oxygen from the air combines with carbon and sulphur elements to produce a volume of gas three times that which the original bisulphid would produce on evaporation. The gases produced, carbon dioxid and sulphur dioxid, in the proportion of 1 to 2, seem just as effective as bisulphid of carbon,

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[1] Simpson, F., 1911. Ground squirrel eradication. California State Board of Health Bulletin, No. 8, Vol. 6, pp. 507-512.

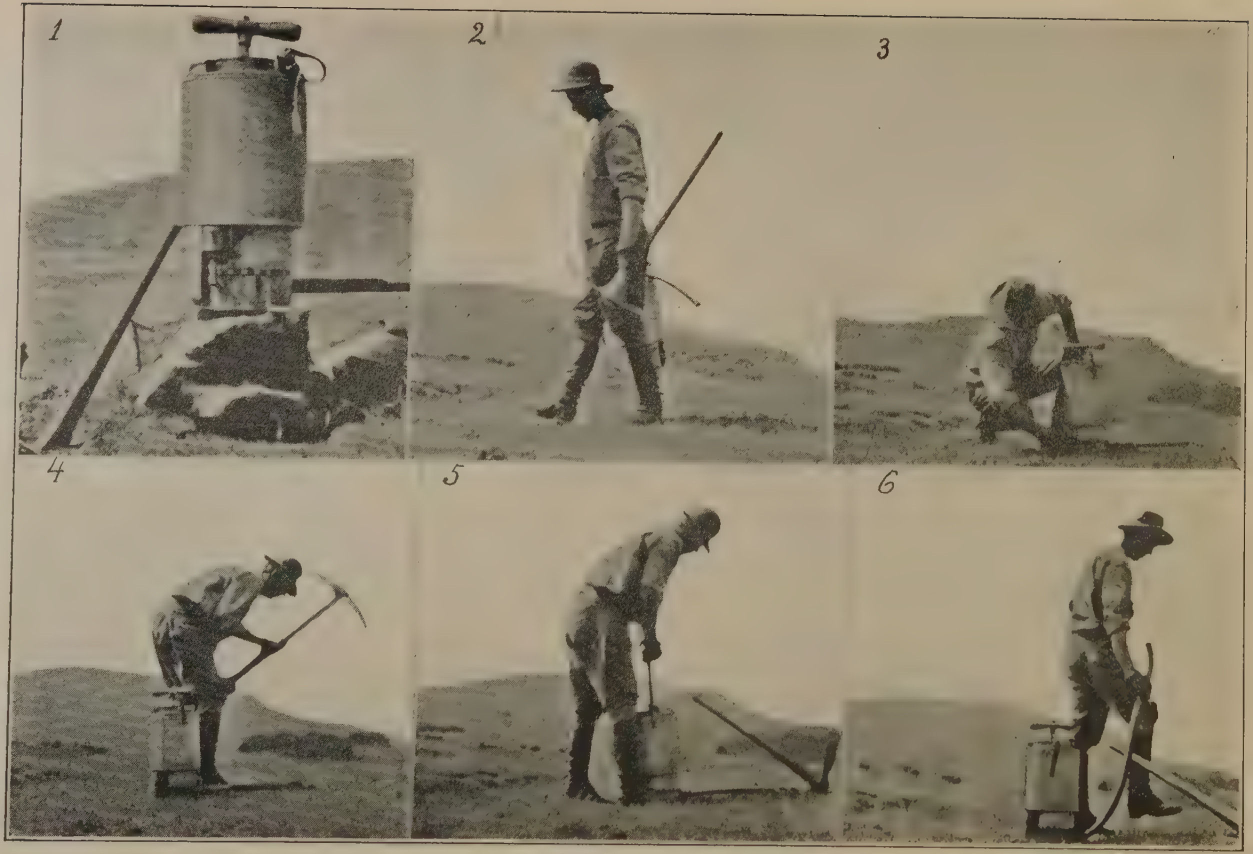

Fig. 183.—Squirrel destructor and its use. (1) The entire outfit ready for use; (2) Man with outfit looking for squirrel burrows; (3) Destructor in position, showing hose inverted in burrow and operator measuring off one half ounce of carbon bisulphid; (4) Closing the mouth of the burrow around the hose while the carbon bisulphid is running into the vaporizing chamber; (5) Operator pumping 30 strokes and forcing into burrow 12 cu. ft. of a 1.5 per cent vapor of carbon bisulphid; (6) Operator closing with heel the hole in the burrow mouth on withdrawal of hose. (U. S. Public Health Service. By permission.)

and the method is superior in that the explosion produced drives these gases deeply into the burrow." Two ounces or 60 cc. of the bisulphid produces about twelve gallons of gas.

To use the gas unexploded simply omit igniting it.

A much cheaper and more efficient method of destruction with carbon bisulphid has been devised by Long[1] and others, namely, a pump with a device measuring the quantity of liquid, and serviceable at all seasons of the year. The pump loaded with nine pints of bisulphid weighs twenty-five pounds. Refined bisulphid should be used in this pump because the metal is rapidly corroded by the crude material. The refined bisulphid is said to contain 99.92 per cent carbon bisulphid and 0.08 per cent sulphur in solution and no hydrogen sulphid nor sulphuric acid.

Only one half ounce (15 cc.) is required for each hole against two ounces by the ignition method, and it is claimed that the men using the pump have been able to treat from 200 to 250 holes with each gallon of the bisulphid, against 50 to 60 holes per gallon with the waste ball method above described.

The use of the apparatus is thus described (see Fig. 183): "Insert the hose in the squirrel hole at least one foot; then run one half ounce of bisulphid from the reservoir into the measuring cup; then turn cock with handle down to allow liquid to run into vaporizing chamber, meanwhile covering the hole with dirt with the aid of a mattock. Then pump thirty strokes (in cold weather use one ounce with forty strokes). This equals 12 cubic feet or 1.5 per cent bisulphid gas. Withdraw the hose, close hole opening by stamping in the dirt with the heel and proceed to the next hole." Twenty minutes' to a half hour's treatment with air containing 2 per cent of carbon bisulphid is certain to be fatal.

(3) *Squirrel Poisoning.*—In the use of poison for squirrels several important factors must be considered, namely, it must not be distasteful to the rodents and must enter the circulation readily; the poison must be applied to food readily eaten by the squirrels and at a time when the usual green food is at its minimum. It has been found that strychnia sulphate (the pure alkaloid should not be used) is most effective, but the bitter taste must in some manner be concealed. The use of whole barley, i.e., threshed but still retaining the husk, is recommended by the U. S. Biological Survey. In this form the barley is not eaten by birds and is most acceptable to the squirrels; it is also cheaper in this form. Wheat is very acceptable to the rodents but when poisoned is very destructive to birds, particularly quail, doves and other grain eaters.

Piper of the U. S. Biological Survey has devised a formula whereby the bitter taste of the strychnin is delayed about two minutes, thus enabling the squirrel to fill its cheek pouches before the bitter taste is noted,—the formula is as follows:

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[1] Long, John D., 1912. A squirrel destructor. U. S. Pub. Health Reports No. 98 (Reprint).

Formula for Strychnin-coated Barley.—Following is the latest government formula[1] for preparing poisoned barley for California ground squirrels.

Barley (clean grain)	16 quarts
Strychnin (powdered alkaloid)	1 ounce
Bicarbonate of soda (baking soda)	1 ounce
Thin starch paste	¾ pint
Heavy corn sirup	¼ pint
Glycerin	1 tablespoonful
Saccharin	⅒ ounce

Mix thoroughly 1 ounce of powdered strychnin (alkaloid) and 1 ounce of common baking soda. Sift this into ¾ pint of thin, hot starch paste and stir to a smooth, creamy mass. (The starch paste is made by dissolving 1 heaping tablespoonful of dry gloss starch in a little cold water, which is then added to ¾ pint of boiling water; boil and stir constantly until a clear, thin paste is formed.) Add ¼ pint of heavy corn sirup and 1 tablespoonful of glycerin and stir thoroughly. Add ⅒ ounce of saccharin and stir thoroughly. Pour this mixture over 16 quarts of clean barley and mix well so that each grain is coated.

Caution.—All containers of poison and all utensils used in the preparation of poisons should be kept PLAINLY LABELED and OUT OF REACH of children, irresponsible persons, and live stock.

According to Simpson (*loc. cit.*) grain poisoned with strychnin placed in proper containers will retain its poisonous character and remain effective for an indefinite period, but heavy dews and rain may remove the poison and destroy the efficiency of the grain in this respect. Therefore this method is applicable during the dry season only. The above author states that thirty kernels in the cheek pouches of squirrels rapidly prove effective, whereas sixty or ninety or more in the stomach may produce only a few convulsions and recovery ensues. He says, "This fact should be remembered in placing poison, for by scattering the grain a few kernels here and there near the burrow the squirrel is induced to store the grain temporarily in the cheek before a sufficient quantity is obtained for a meal. . . ." It should be scattered where the squirrel is accustomed to find food, and will probably be found most efficient if placed early in the morning, between the hours of 3 A.M. and 7 A.M.

The Chigoe Flea (*Dermatophilus penetrans* Linn.), known as "jigger," "chigger," "chique," or "sand flea," is a tiny burrowing flea (Fig. 184) found in the tropical and antitropical regions of North and South America, also in the West Indies and Africa. Its introduction into Africa is said to have occurred as late as 1872. The chigoe

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[1] Circular letter issued by Bureau of Biological Survey, U. S. Dept. Agric., June, 1917.

is a reddish brown flea about 1 mm. in length, except that the impregnated female may become as large as a small pea, the head is proportionately large, there are no ctenidia on the head and thorax, the palpi are four-segmented and the mouth parts are conspicuous. The adult fleas are intermittent feeders but adhere closely to the host, the female when impregnated proceeds to burrow into the skin of the host. The eggs are deposited either in the ulcer or drop to the ground when discharged from the body of the female. The larvæ which emerge in a few days from the eggs are typical flea larvæ. Those hatching in the ulcer drop to the ground to develop under conditions similar to those having hatched on the ground. The larval period under favorable conditions probably requires not more than ten to fourteen days and the cocoon or pupal period about a like number of days.

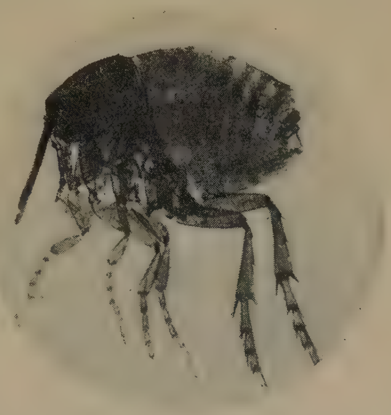

Fig. 184.—The chigoe flea, *Dermatophilus penetrans.* × 35.

Pathogenesis.—The chigoes commonly attack the bare feet, these being nearest the ground, infesting the skin between the toes, and the soles; no part of the body is really exempt from attack. The burrowing female flea causes extreme irritation; the area surrounding the flea becomes charged with pus, producing a distinct elevation. The ulcerations due to the presence of numerous chigoes become confluent and very grave results are often involved. Wellman attributes the commonly observed auto-amputation of toes to the work of the chigoe.

Treatment and Control.—Where the chigoe flea commonly occurs, the habitations of humans and of domesticated animals (for these are also subject to attack) must be kept clean and free from dust, the floors may be swept up with a liberal sprinkling of naphthalene flakes, or with fresh buhach or pyrethrum powder. Where possible, kerosene treatment should be applied as described above for other fleas. Walking in bare feet should be avoided.

Parts of the body attacked by the fleas should receive immediate attention. The insect can be removed quite easily by means of a sterile needle or very fine pointed knife blade. The wounds caused by this treatment are then carefully dressed and allowed to heal. Applications of turpentine or other remedies serve to kill the fleas, which are then discharged by ulceration.

The Hen Flea, *Echidnophaga* (*Xestopsylla*) *gallinaceus,* Westw., also known as the "stick tight" of poultry, is one of the worst poultry pests in many parts of subtropical America (Fig. 185). It commonly attacks poultry of all kinds, also cats, dogs, horses and even humans. Osborn (*loc. cit.*) states that this species differs from the foregoing "in having the hind angles of the metathoracic scales angled instead of rounded and the eyes and antennæ in the posterior half of the head. It is from 1 to 1½ mm. in length."

Before copulation both sexes are active, hopping about much as do other species of fleas. Shortly after feeding begins the females attach themselves firmly to the skin of the host and begin to burrow. At this time the sexes are in copulation. The burrowing females deposit their eggs in the ulcers which have been produced by the infestation. The larvæ crawl out of the ulcer and drop to the ground, where they grow rapidly under favorable conditions, feeding on nitrogenous matter, dry droppings, etc. The full-grown larva, which is not unlike other flea larvæ, is about 4 mm. in length, having reached this stage in evidently about 2 weeks. The larva then spins a cocoon, pupates and in about 2 weeks emerges as a full-developed flea. The life history requires about 4 weeks, more or less, based on rather crude observations. The writer believes also that eggs are deposited in the dust or dry droppings of poultry, or in old nests, etc.

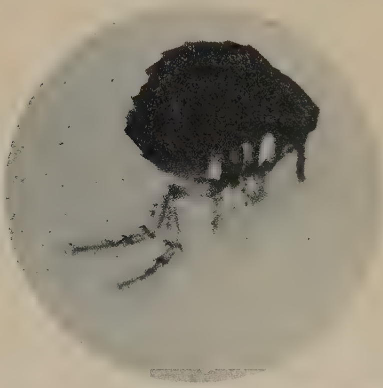

FIG. 185.—*Echidnophaga gallinaceus*, the chicken flea or stick tight. × 25.

The fleas are most likely to attack the skin around the eyes or the anus or other bare spots. The ulceration and wart-like elevations around the eyes often become so aggravated that blindness results, the host is unable to find its food and death results.

To control the hen flea a thorough cleaning up is very necessary. The débris, dust, etc., must either be burnt or treated liberally with kerosene right in the yard so that the fleas do not become distributed while carrying away the refuse. The writer recommends that the yards and coops, particularly crevices, be thoroughly scalded out by liberal applications of boiling water or by the use of kerosene or a light fuel oil applied with a spray pump. Coops and yards which have crude oil floors are comparatively free from fleas and other parasites if otherwise kept in good condition. The hot water or oil treatment must be repeated once every three or four weeks during the flea season. The use of sheep dips, carbolic-acid sprays, etc., does not, as a rule, give good results in controlling chicken fleas.

In addition to the above treatment infested chickens must also receive attention in order to destroy the ovulating female fleas. This may be done by dipping the birds in a 5 per cent solution of Zenoleum, Kreso or even Creolin. The use of naphthalene flakes in the nests is recommended or if this seems undesirable a liberal layer of slaked lime in the bottom of the nest may be substituted.

B. Louse Flies and Forest Flies

Order Diptera (Pupipara) Family Hippoboscidæ

Characteristics of Hippoboscidæ.—The family Hippoboscidæ is characterized by Williston as follows:

> "Head flattened, usually attached to an emargination of the thorax; face short; palpi forming a sheath for the proboscis, not projecting in front of head; antennæ inserted in pits or depressions near the border of the mouth, apparently one jointed, with or without a terminal bristle or long hairs. Eyes round or oval (sometimes very small); ocelli present or absent. Thorax flattened, leathery in appearance; scutellum broad and short. Halteres small or rudimentary. Abdomen sac-like, leathery in appearance, the sutures indistinct; legs short and strong, broadly separated by the sternum; tarsi short; claws strong and often dentated. Wings present or absent. . . . They are all parasitic in the adult condition upon birds or mammals. (The larvæ are pupiparous, but pass nearly the whole of this stage within the abdomen of the parent, being extruded when nearly ready to transform into the mature fly)."

The mouth parts are tubular and are fitted for sucking blood. The most important species is the sheep tick or sheep louse fly, *Melophagus ovinus* Linn.

The Sheep "Tick," or "sheep-ked," *Melophagus ovinus* Linn. (Fig. 186), is a wingless species, reddish brown in color, about 5 to 7 mm. in length. The head is short and sunken into the thorax, the body is sac-like, leathery and spiny.

Life History.—The young of the sheep tick leave the body of the female ready to pupate. The extruded pupa (Fig. 186) during the course of a few hours becomes chestnut-brown in color, the secretion with which it is covered hardens and serves to glue the pupa firmly to the wool of the sheep. The pupæ are commonly found on infested sheep in the region of the shoulders, thighs and belly. Pupæ may be found on sheep at all times of the year, though the time required for development in the winter is longer than in the summer. Swingle[1] who has carried on most careful observations on this insect states that pupæ require from 19 to 23 days to hatch in the summer, whereas 19 to 36 days are required during the winter on sheep kept in the barn and probably 40 to 45 days on sheep out of doors. The time required for the females to reach sexual maturity is from 14 to 30 days and over, when they begin extruding young at the rate of one about every 7 or 8 days. Swingle regards about 4 months as the average life of a sheep tick and that from ten to twelve pupæ are deposited on an average.

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[1] Swingle, Leroy D., 1913. The life history of the sheep-tick, *Melophagus ovinus.* Univ. of Wyoming Agr. Exp. Sta. Bull. No. 99.

The whole life of the tick is spent on the host; when off the sheep the insects die in from 2 to 8 days, most of them dying in about four days.

Pathogenesis.—The presence of a few louse flies on the bodies of sheep does not materially affect them. Ordinarily the presence of the insect is indicated by the fact that the animal rubs itself vigorously, bites the wool and scratches. Badly infested animals show emaciation and general unthriftiness.

Control.—Since the principal time for migration from the sheep to the lambs is at shearing when the insects are taken off the hosts with the wool, it is wise to take particular pains at this time to store the wool at some distance from the lambs. Inasmuch as the ticks die within a week when away from the host, and cannot well crawl any great distance, the above suggestion is well worth considering. Swingle states that "a sheep free from ticks can be kept for months beside a heavily infested one with a tight partition only three feet high between them without becoming infested. . . . A bunch of females placed in the wool of a sheep will be found in practically the same place for two days. Males, however, are more inclined to migrate." A flock of sheep once freed from ticks can therefore be kept clean unless infested animals are introduced.

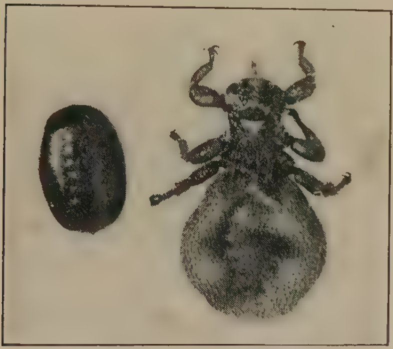

FIG. 186.—The sheep tick or louse fly, *Melophagus ovinus.* Pupa (left), adult (right). × 4.5.

The writer has reasons to doubt the efficiency of the usual sheep dips such as "lime and sulphur" and tobacco decoctions in the destruction of the sheep tick; however, other dips, such as Kreso, Zenoleum and Chloronaphtholeum, if used as directed for sheep scab mites will kill the "ticks" but not the pupæ. The time for the second dipping is governed by the life history of the parasite, hence in warm weather (dipping for ticks is best done in the autumn), the second dipping should take place in about twenty-four days after the first.

No doubt a liberal use of buhach or pyrethrum powder, particularly as a winter treatment, would prove beneficial.

Louse flies of deer.—*Lipoptena depressa* Say (Fig. 187) is an exceedingly common parasite of the blacktailed deer. This species is smaller than *Melophagus ovinus,* otherwise resembling it; it is wingless when found on the host, but has well-developed filmy wings which are evidently lost later on (Fig. 187). These parasites have been found in chains, three or four attached to each other, the first tick drawing blood from the host, the second with its proboscis thrust into the abdomen (dorsally) of the first, the third drawing on the second and so on to the last most lucky individual. *Lipoptena cervi* Linn. is said to be a common European species on deer.

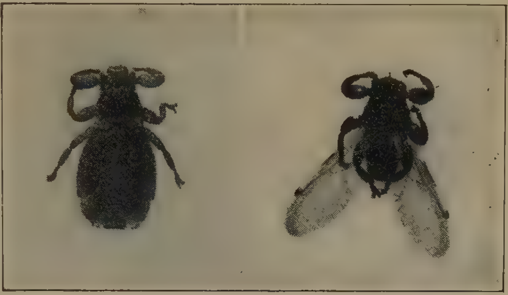

Fig. 187.—Louse fly of the deer (*Lipoptena depressa*), showing wingless and winged form. × 5.

The forest fly or louse fly of the horse is *Hippobosca equina* Linn. This species is quite large (length 8 mm.), is winged and a fairly good flier. It is common in many parts of the world but occurs rather infrequently in America. The damage which it does would depend entirely on its abundance.

Louse flies of birds and bats. Pigeons of the Mediterranean regions are said to be commonly infested by *Lynchia maura* Bigot which is also a carrier of so-called "pigeon malaria." *Lynchia pusilla* Speiser is an American species. *Olfersia americana* Leach inhabits American owls, and *Nycteribia antrozoi* Town. and *N. mexicana* Bigot inhabit bats.

CHAPTER XVIII

TICKS

Class Arachnida, Order Acarina, Superfamily Ixodoidea

Characteristics of Arachnida.—The general characteristics of the class Arachnida have already been pointed out in an earlier chapter, but it is in place to refer to these once more. Adult arachnids with a few exceptions have four pairs of legs (the larvæ are commonly hexapod), wings are absent as are antennæ and compound eyes. Simple eyes may be present or absent; when present they are often more than two in number. The mouth parts usually consist of a pair of piercing cheliceræ. The respiratory organ in some arachnids, for example spiders, is called a "lung book"; in many species, however, particularly ticks, there is present a well-defined tracheal breathing system. The body is commonly divided into two parts,—cephalothorax and abdomen, the former bearing the walking appendages. In many species, for example, the ticks and mites, the regions of the body are fused. The sexes are distinct and there is often marked sexual dimorphism.

Order Acarina.—To the order Acarina belong the ticks and mites. The cephalothorax and abdomen are fused, the larvæ have only three pairs of legs; the eyes in the parasitic forms are either very small or entirely wanting. The members of this group are never large, some ticks may be 15 to 16 mm. in length, while many of the mites are barely visible to the naked eye.

The Ticks.—The ticks are acari varying in size from 1 mm. in the seed tick or larval stage to about 15 mm. in the fully engorged mature female of several species. They are found in all parts of the world and are commonly regarded as pests of domesticated animals and frequently attack man. Snakes, lizards and toads serve as hosts for some species.

The ticks belong to the superfamily Ixodoidea. They are blood-sucking arachnid parasites, body covered with a leathery, more or less glossy cuticle, the head or capitulum consisting of characteristic protrusible cheliceræ and a serrate hypostome (Fig. 188). The females are capable of very great distention, having the appearance of a seed rather than that of an arthropod.

Life History.—The life histories of ticks vary considerably for the several species, hence it is quite impossible to generalize, except that it may be said that all species of ticks pass through four stages,—*egg, seed tick, nymph* and *adult* and that from six weeks to over six months are required to pass through these four stages. Eggs are deposited by the fully engorged females, the number varying from 100 in some species to 5,000 and over in others. The newly hatched larvæ, known as seed ticks, are hexapod (six-legged) and remain in this condition until the first molt. The nymph emerges from the first molt with its fourth pair of legs present, and remains in this stage until the second molt, after which the adult tick emerges; often a third or even a fourth molt or more takes place before the adult stage is reached. Copulation takes place after the last molt, when the females engorge and then deposit eggs. In the majority of species, the ticks drop off the host animal to molt, but in several species, notably the Texas cattle fever tick (*Margaropus annulatus*), the molting takes place on the host. Eggs are invariably deposited on the ground by the fully engorged females. There may be two or possibly three generations of ticks in one year under very favorable climatic conditions in such species as molt on the host.

The seed ticks emerging from the eggs on the ground commonly climb up grasses and other low vegetation, thus coming in easy reach of grazing or passing animals. The nymphs employ the same method.

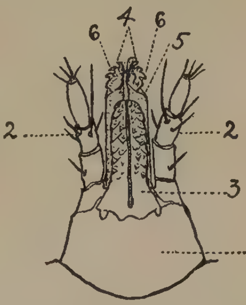

Fig. 188.—Capitulum of a tick (larval Argas), ventral aspect, showing (1) basis capituli; (2) palpi; (3) hypostome; (4) chelicerae; (5) hood or sheath of chelicerae; (6) denticles of chelicerae. (Drawing by W. L. Chandler.)

Tick Mouth Parts.—The capitulum or head bears the mouth parts and accessory external structures (Fig. 188). The basal portion is known as the *basis capituli,* from which projects forward and dorsally a pair of protrusible *chelicerœ.* The distal portions (*digits*) of the chelicerae are divergent and provided with recurved teeth. Projecting forward and situated ventrally and median on the *basis capituli* is the *hypostome* bearing many recurved teeth. Laterally are located the *palpi* (one pair), consisting of four articles, of which two or more may be used,—commonly only three are visible.

Feeding Habits.—When sucking blood both the hypostome and the chelicerae are inserted into the tissue of the host. Because of the recurved teeth the tick is enabled to hold so fast to the host that it is difficult to remove it without tearing the capitulum from the body of the tick. The tick itself, however, withdraws its mouth parts quickly and apparently with little effort by slipping the hoodlike portions of the capitulum over the relaxed mouth parts and by means of a quick jerk drops off and escapes.

The length of time that a tick remains attached in the act of feeding depends entirely on the species and the stage of development. The seed ticks commonly feed for a number of days; the nymphs and adults differ greatly in this respect,—thus the common poultry tick (*Argas persicus*) feeds nightly and intermittently, while the nymphs and adults of the cattle tick (*Margaropus annulatus*) feed from six to eight days before becoming engorged. Other species of ticks, notably the Pajaroello (*Ornithodorus coriaceus*), engorge themselves fully in from fifteen to twenty-five minutes.

Longevity.—The longevity and hardiness of ticks is something truly remarkable, a matter not to be overlooked in control measures, particularly pasture rotation in which starvation is the principal factor. Furthermore, fluids which destroy the life of most insects in a few minutes act very slowly on these arachnids, for example, immersion in 70 per cent alcohol will not kill the ticks for hours and xylol is resisted for about half an hour. The writer has found the poultry tick *Argas persicus* particularly resistant.

Unfed larval ticks of the above species remain alive quite readily for a month and would probably survive longer if kept in a moist chamber. Nymphs survive a longer time and the adults even longer than the nymphs. Nuttall[1] cites cases in which nymphs of this species survived two months, and adults (unfed) "a little over two years." Graybill[2] reports considerable variation in the longevity of the Texas fever tick, depending on the season of the year; unfed larvæ survived from 7 to 85 days (aver. 38.6) for July, and 30 to 234 days (aver. 167.4) for October. Nuttall[3] cites cases in which the larvæ of *Ixodes ricinus* survived 19 months, unfed nymphs 18 months and unfed adults 15 to 27 months.

Major Divisions (classification).—All ticks (superfamily Ixodoidea) are commonly divided into two families, viz.: Argasidæ (also referred to as subfamily Argasinæ) and Ixodidæ (also referred to as subfamily Ixodinæ). The presence of a *scutum* (or shield) located dorsally immediately posterior to the capitulum in the Ixodidæ is the most striking differential character. This character is absent in the Argasidæ.

The following table adapted after Nuttall (1908, *loc. cit.*), will be found useful in separating the two families. (See also Fig. 189.)

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[1] Nuttall, G. H. F., and Warburton, Cecil, 1908. Ticks, a monograph of the Ixodoidea. Part I, Argasidæ. Pp. x + 104 + 35. Cambridge (England) Univ. Press.

[2] Graybill, H. W., 1911. Studies on the biology of the Texas fever tick. U. S. Dept. of Agric., Bur. Animal Ind. Bull. No. 130.

[3] Nuttall, G. H. F., and Warburton, Cecil, 1911. Ticks, a monograph of the Ixodoidea. Part II, Ixodidæ. Pp. xix + 105 + 348. Cambridge (England) Univ. Press.

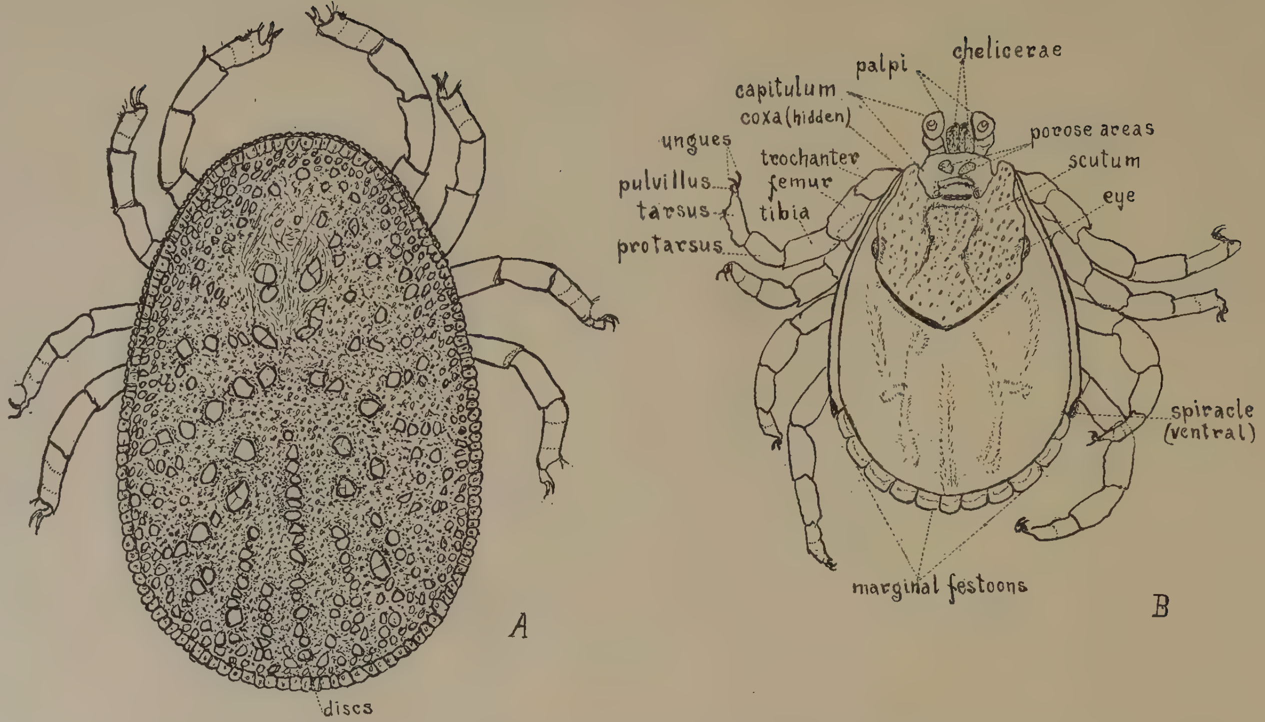

FIG. 189.—Showing certain useful characters in dorsal view to distinguish A, the Argasidæ (Argas), from B, the Ixodidæ (Dermacentor). (Drawings by W. L. Chandler.)

TABLE XXII

DIFFERENCES BY WHICH THE TWO FAMILIES OF THE IXODOIDEA MAY BE SEPARATED. (ADAPTED AFTER NUTTALL.)

	ARGASIDÆ	IXODIDÆ
Sexual dimorphism	Slight	Marked
Capitulum	Ventral	Anterior
Base	No porose areas	Porose areas in ♀
Palpi	Leg-like, with subequal articles	Relatively rigid, of very varied form
Body		
Scutum	Absent	Present
Festoons	Absent	Generally present
Eyes (when present)	Lateral on supracoxal folds	Dorsal on the sides of the scutum
Legs		
Coxæ	Unarmed	Generally armed with spurs
Tarsi	Without ventral spurs	Generally armed with 1 or 2 ventral spurs
Pulvilli	Absent or rudimentary	Always present

THE IXODINE TICKS

The Texas Cattle Fever Tick

The Texas Cattle Fever Tick (*Margaropus annulatus* Say = *Boöphilus bovis* Riley) is economically considered the most important species of the family Ixodidæ (Fig. 190). It is restricted to North America, where it occurs south of the Mason and Dixon line. It is typically a cattle tick, although it occurs at times in smaller numbers on deer, sheep and other animals.

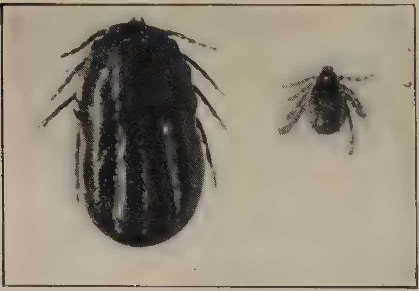

FIG. 190.—The Texas fever tick, *Margaropus annulatus*; female (left) and male (right). × 3.5.

Fully engorged females range in length from 10 to 12 mm., while the males range from 3 to 4 mm. The body of the female is about equally rounded both posteriorly and anteriorly with a slight median incurving. The anterior pair of legs is set well out on the shoulders away from the capitulum (in Dermacentor close to the capitulum). The palpi are very short and stalky, so that the entire capitulum or head is inconspicuous. The relatively small (1 + mm. long) scutum or shield is solid chestnut brown in color. This is commonly the only species of tick in some localities with a chestnut-brown scutum. Two other species of ticks with a chestnut-colored scutum occur occasionally with the Texas fever tick, namely the "Lone Star Tick," *Amblyomma americanum,* which has, however, a distinct silver white circular spot at the posterior end of the scutum, and *Ixodes ricinus* and its varieties, e.g., *californicus,* in which the capitulum is long, and the anterior pair of legs attached close to it. Other technical diagnostic details are, of course, present in the latter two species.

The stigmal plates of *M. annulatus* are nearly circular; the porose areas are elliptical and far apart.

Economic Importance.—It has been estimated[1] that the annual losses to the South (U. S.) occasioned by the "cattle tick" directly and indirectly prior to 1906 amounted to $130,500,000. These losses are summed up as follows:

"1. Death, from Texas fever, of pure bred cattle imported from the North for breeding purposes.

"2. Death, from Texas fever, when cattle reared in isolated tick-free areas are unintentionally or accidentally placed with ticky cattle, or on tick-infested areas.

"3. Death of native cattle from excessive parasitism and fever, occasioned by the ticks.

"4. Universal loss of weight by all tick-infested cattle, and their failure to gain flesh at a rate great enough to make beef production profitable.

"5. The lower price which 'Southern' cattle bring upon the market, regardless of how perfect their condition may be.

"6. Sterility induced in high-grade cattle by tick infestation.

"7. The expense of maintaining the Federal quarantine for the protection of the North against invasion by the tick, and the added expense of maintaining quarantine pens for Southern cattle shipped north for slaughter.

"8. The discouraging effect on the breeding of pure bred cattle in the South by reason of Southern breeders not being allowed to exhibit in Northern show rings.

"9. By no means least, the potential loss in fertility of Southern farm lands due to a one-crop system which, with the tick eradicated, would quickly give way to a diversified agriculture which would conserve and increase the fertility of our soils."

From 1906 when coöperative tick-eradication work was undertaken between the U. S. Bureau of Animal Industry and State authorities, to December, 1918, a total of 458,529 square miles of territory has been released from quarantine against Texas cattle fever which speaks well for the methods employed.[2]

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[1] State Crop Pest Commission of Louisiana, 1906. Circ. No. 10, "The cattle tick."

[2] Ellenberger, W. P., and Chapin, R. M. Cattle-fever ticks and methods of eradication. U. S. Dept. of Agric., Farmers' Bull. No. 1057.

Life History of Texas Fever Tick.—Most careful observations on the biology of the Texas fever tick have been made by the Bureau of Animal Industry of the U. S. Department of Agriculture and the following data is adapted after Graybill (1911, *loc. cit.*). The maximum number of eggs deposited by a female tick according to this author was 5,105, minimum 357, with an average ranging from 1,811 to 4,089. The period of oviposition, time during which female deposits eggs, ranged from an average of 8.3 days for June (1907) to 127.5 days for November. The maximum period was 152 days and the minimum 3 days, depending on temperature mainly. The incubation period, also dependent on temperature, ranged from 19 days in summer to 180 days in the early autumn, with the average of 43.6 days for April, 26.3 days for May, 24.5 days for June, 20.5 days for July, 21.2 days for August and 35.9 days for September. The hatching period depends on the time when the eggs are laid, the eggs first deposited ordinarily hatching first. The average period ranged from 10.6 days for July to 36 days for October, with a maximum period of 49 days and a minimum of 4 days. The time during which the seed ticks remain alive, i.e., longevity of the newly hatched ticks, again varies considerably, depending on temperature; the longevity for April was found to be 65.1 days, May 62.3 days, June 65.1 days, July 38.6, August 84.9 days, October 167.4 days. The total average time for the non-parasitic period ranged from 86.9 days for June to 279.6 for October.

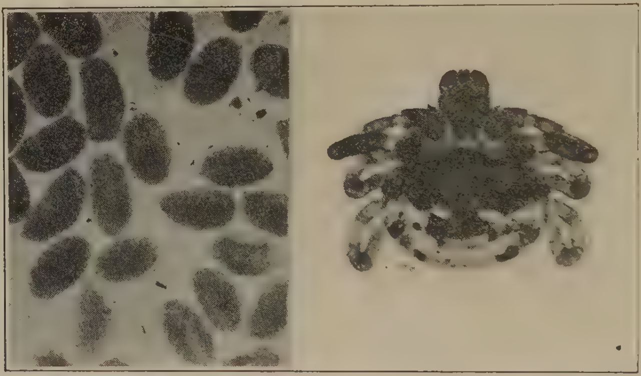

FIG. 191.—Eggs (left), larva (right), of the Texas fever tick, *Margaropus annulatus.* × 50.

The three stages (Fig. 191) considered in the parasitic period of the ticks are larval (seed tick), nymphal and adult. As Graybill has well said, "The duration of each of these stages and the duration of a single infestation upon cattle during different portions of the year are of great practical importance. Upon the duration of an infestation depends the time animals must be kept on the tick-free fields in order to become free from ticks." This author has found that after the seed tick has attached itself to the host the minimum larval period ranges from 5 to 7 days, the minimum nymphal period of females from 9 to 30 days, and the adult from 5 to 33 days, with a total period of infestation, including the time for molting twice, which is accomplished on the host, at from 30 to 66 days.

The more striking differences between the life histories and a comparison of the life cycle of the Texas fever tick and the common dog tick (*Dermacentor electus*) are shown in the following two tables Tables XXIII and XXIV), adapted after Cotton: [1]

TABLE XXIII

COMPARISON OF THE LENGTH OF THE LIFE CYCLE OF THE DOG TICK AND OF THE NORTH AMERICAN FEVER TICK IN SUMMER

(After Cotton, *loc. cit.*, 1908)

DOG TICK (*Dermacentor sp.*)	NORTH AMERICAN FEVER TICK (*Margaropus annulatus*)
I. Adult tick becomes engorged on host animal and drops to ground	Adult tick becomes engorged on host animal and drops to ground
II. Engorged tick begins egg laying (3000 ± eggs) after 3–5 days	Adult tick begins egg laying (3000 ± eggs) after 3–5 days
III. Seed ticks hatch from eggs in about 30 days	Seed ticks hatch from eggs in about 30 days
IV. Seed ticks bunch on grass and await coming of host animal, from one day to several weeks	Seed ticks bunch on grass and await coming of host animal from one day to several weeks
V. After feeding 7–12 days seed ticks drop to ground and molt	After feeding 7–12 days seed ticks molt *on* host animal
VI. Ticks crawl up on grass and await coming of second host animal from one day to several weeks	
VII. Ticks get on second host animal and feed 5–10 days, then *drop to ground* and molt second time	Ticks feed 5–10 days, then molt on host animal and mate
VIII. Ticks crawl up on grass and await coming of third host animal from one day to several weeks	
IX. Adult ticks mate and feed 5–8 days, then drop to the ground and lay eggs	Adult ticks feed 4–14 days then drop to the ground and lay eggs

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[1] Cotton, E. C., 1908. Tick eradication. Agr. Exp. Sta. of the Univ. of Tennessee Bull. No. 81.

TABLE XXIV

SHOWING PROMINENT DIFFERENCES BETWEEN THE LIFE HISTORIES OF THE DOG TICK AND THE NORTH AMERICAN FEVER TICK

(After Cotton, *loc. cit.*, 1908)

DOG TICK (*Dermacentor sp.*)	NORTH AMERICAN FEVER TICK (*Margaropus annulatus*)
Leaves host animal for each molt	Never voluntarily leaves host animal from attachment as a seed tick until fully mature
Requires three separate host animals or may get on same host three times	Requires but one host animal to reach maturity and gets on this one animal but once
Can develop on a large number of different kinds of animals	Must find cow, horse, mule (deer or sheep) as a host animal or perish
Does not transmit Texas fever	Only natural means of transmission of Texas fever from one cow to another
Usually requires a whole year to complete its life cycle, from egg through seed tick, nymph, and adult, to egg again	Is able to complete its life cycle in about 60 days, thus allowing for three generations in one year, provided hosts are available
Because of the habit of dropping to the ground at each molt the parasitic and non-parasitic periods intermingle and therefore the life cycle cannot be divided into two distinct parts	Life cycle is divided into two separate and distinct parts; *parasitic*, passed *on* the host animal, and *non-parasitic*, passed *off* the host animal
The habit of dropping to the ground for each molt materially reduces the chances of the seed ticks of this species reaching maturity	The habit of remaining on the host animal until maturity renders it almost certain that every seed tick of this species finding attachment will reproduce itself
Since the species has but one generation per year the progeny of one adult tick will produce 1,050,000 eggs in a single season	Since this species has three generations per year the progeny of one adult tick will produce 5,825,036,452,578,000 eggs in a single season

Piroplasmosis applies to a group of diseases traceable to the Protozoön genus Babesia (Piroplasma), and related genera such as Theileria, Nuttalia, etc., belonging to the subphylum Sporozoa, class Telosporida, subclass Hæmosporida, order Xenosporida. The genus Babesia comprises pear-shaped (varying somewhat to oval), red blood-cell inhabiting parasites (Fig. 192). Unlike the Plasmodia there is little or no pigment, and multiplication is by division in twos. Ticks are the usual carriers in which there may be a so-called hereditary transmission from the female tick to the egg, and thus to the larva and nymph which act as the infecting agents. The most important example of Piroplasmosis is Texas cattle fever.

Texas Cattle Fever.—*Babesia* (*Piroplasma*) *bigemina*, Smith and Kilbourne, is the causative organism of Texas cattle fever, also variously known as red water, splenic fever, tick fever, etc. The disease is widely distributed, being endemic in southern Europe, Central and South America, parts of Africa, Mexico, the Philippines, and the southern United States where it has been known for more than a century, having been introduced into this country probably from Europe.

The name Texas fever became attached to the disease because of the large herds of cattle which were driven northward from Texas and gave a certain disease in some mysterious manner to Northern cattle that crossed the trail of the Southern cattle. The first account of the disease was given by James Mease in 1814 before the Philadelphia Society for Promoting Agriculture. In 1879, Salmon began an investigation of the disease; and in 1889, Theobald Smith made his epoch-making discovery of the intracorpuscular protozoan parasite inhabiting the blood of the diseased cattle. Immediately thereupon followed the experiments of Kilbourne, on suggestion of Salmon, which proved the disease to be tick-borne, a suspicion held as early as 1869 according to Smith and Kilbourne. Until that time (1889) infection was variously attributed to saliva, urine or feces.

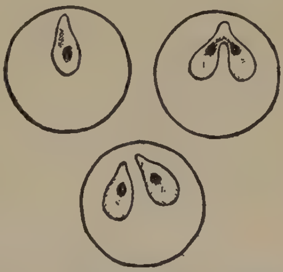

Fig. 192.—*Babesia bigemina* (*Piroplasma bovis*), showing three stages in intracorpuscular development. × 2000.

The disease may assume either an acute or chronic form, the acute occurring during the summer months and the chronic during the autumn and early winter. The symptoms[1] of the acute form are as follows: The temperature often registers 106° to 108° F. within forty-eight hours after the first symptoms are noticed. The sick animal leaves the herd, stands with arched back and ears drooping, the muzzle dry, appetite lost and rumination stopped. There is constipation during the first stage of the disease, which may give way to diarrhea later. The manure is frequently stained with bile and may be tinged with bloody mucus; the urine is often very dark red or coffee-colored. The blood becomes thin and watery, so that by making an incision into the tip of the ear and allowing the blood to flow over the hand it does not stick to the hand as does the blood from a healthy animal.

Vast numbers of red blood corpuscles are destroyed by the parasites, which accounts in a measure for the reddish color of the urine through the elimination of hæmaglobin by the kidneys; and it is believed that the excessive work that the liver has to perform in attempting to transform the excess of destroyed corpuscles into bile, causes this organ to become deranged in function, and eventually a complete stagnation may result with fatal termination. Mortality ranges from fifty to seventy-five per cent.

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[1] Adapted largely after the description of L. L. Lewis, 1908. Texas fever. Okla. Agr. Exp. Sta. Bull. No. 81.

The chronic form of the disease is often hardly noticeable. The following comment by Lewis (*loc. cit.*) is significant: "This is the type of fever usually seen among Southern cattle. Death does not occur as a rule, but the loss in growth and general condition is such as to make this type of disease very important. It is this loss in growth and condition rather than an actual numerical loss by death that constitutes the great damage suffered by the stock industry of the South."

Babesia bigemina = (Piroplasma bovis bigeminum Smith and Kilbourne), the causative protozoan parasite of Texas cattle fever, was discovered by Theobald Smith in 1889 and was called *Pyrosoma bigeminum.* The parasite (Fig. 192) is described by Smith and Kilbourne[1] as follows:

> "When blood is drawn from the skin during the fever, and examined at once with high powers (500 to 1000 diameters . . .) certain corpuscles will be found containing two pale bodies of a pyriform outline. One end of each body is round and the body tapers gradually to a point at the other. They vary somewhat in size in different cases, but the two bodies in the same corpuscle are as a rule of the same size. They are from 2 to 4 μ in length and 1.5 to 2 μ in width at the widest portion. Their tapering ends are directed toward each other and usually close together; their rounded broad ends may occupy various positions with reference to each other. They may be seen together with the axes of the bodies nearly parallel or they may be far apart, the axes forming a straight line. The bodies themselves have a homogeneous, pale appearance, contrasting markedly with the inclosing red corpuscles from which they are sharply outlined. There is no differentiation into peripheral and central zone, no granular appearance of the body. . . . When exposed to a temperature of 35° C. to 42° C. on the warm stage some of these bodies, by no means all, exhibited changes of outline. These may go on continuously in some bodies, in others quite slowly. The motion most frequently exhibited consists not so much of a thrusting out and withdrawing of pseudopodia as of a continual recasting of the general outline of the body as we find it, for example, in the leucocytes of mammalian blood. . . . The number of infected corpuscles circulating in the blood during the high fever is usually quite small . . . from half to one per cent is near the truth in most cases. . . . Toward the fatal termination, there may be from 5 to 10 per cent of the corpuscles with the pyriform parasites present."

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[1] Smith, T., and Kilbourne, F. L., 1893. Investigations into the nature, causation and prevention of Texas or Southern cattle fever. U. S. Dept. of Agric., Bur. Animal Ind. Bull. No. 1, 301 pp.

In 1888 an "investigation into the nature, causation and prevention" of the disease was undertaken by the United States Department of Agriculture, Bureau of Animal Industry, under the direction of Dr. D. E. Salmon. The work was done by Dr. Theobald Smith and Dr. F. L. Kilbourne and marks a most important epoch in our knowledge of protozoan diseases and in preventive medicine.

During a period of about four years of nearly continuous investigation, the problem was exhaustively studied in both the field and in the laboratory. The field experiments were carried along three different lines, viz.:

> "(1) Ticks were carefully picked from Southern animals so that none could mature and infect the ground. The object of this group of experiments was to find out if the disease could be conveyed from Southern to Northern stock on the same inclosure without the intervention of ticks. (2) Fields were infected by matured ticks and susceptible cattle placed on them to determine whether Texas fever could be produced without the presence of Southern cattle. (3) Susceptible Northern cattle were infected by placing on them young ticks hatched artificially, i.e., in closed dishes in the laboratory" (Smith and Kilbourne, 1893, *loc. cit.*).

Healthy native cattle (Washington, D. C.) were exposed to sick native cattle free from ticks for months without contracting the disease, proving that the excretions had nothing to do with the transmission of the disease. In the absence of ticks, sick animals are harmless. Again several thousand, mostly full-grown ticks, collected from cattle in North Carolina, were scattered over the ground in a field on September 13. Four native cattle were placed in the field September 14; of these animals three contracted Texas fever. This experiment was repeated with five experimental animals, and a new-born calf, all of which contracted the fever. A yearling heifer was placed in a box stall and a number of young ticks, hatched artificially in glass dishes, were placed on the animal at intervals. The heifer contracted Texas fever. A repetition of this experiment on various occasions always gave similar results. It was definitely concluded that "Texas fever in nature is transmitted from cattle which come from the permanently infected territory to cattle outside this territory by the cattle tick (*Boöphilus bovis* = *Margaropus annulatus*) and that the infection is carried by the progeny of the ticks which matured on infected cattle, and is inoculated by them directly into the blood of susceptible cattle."

Just how the young tick becomes infected from the parent tick is still a question, but it seems reasonable to conclude that the protozoön migrates from the intestine of the parent, possibly in a manner similar to the development of the malaria parasite, eventually infecting the ovaries instead of the salivary glands as in the mosquito, and thus the ova become infected before ovulation and the newly emerged seed tick is consequently infective. The authors above cited state that the contents of the bodies of ticks in various stages of growth were examined microscopically with considerable care, but that the abundant particles resulting from the breaking up of the ingested blood corpuscles obscured the search so that nothing definite was discovered. "The very minute size of the microörganisms renders its identification well-nigh impossible, and any attempt will be fraught with great difficulties."

Other tick carriers of the protozoön are *Boöphilus australis* Fuller and *B. decoloratus* Koch within their range,—the former Australia, Philippine Islands, South America, and the latter Africa.

Controlling the Texas Fever Tick.—This is accomplished in one of two general ways or by a combination of the two; namely, first by the application of tickicides on cattle, and secondly by pasture rotation resulting in the starvation of the seed ticks which have hatched from the eggs deposited by dropped ticks, the pasture being previously made free of ticks by a similar process. It is not the object of this work to give a detailed account of the methods employed, hence the reader is referred to Farmers' Bulletin 498, U. S. Department of Agriculture, for specific "Methods of exterminating the Texas fever tick."

First, agents for the destruction of ticks on cattle are ordinarily either *oil* or *arsenic*. If the former is used an emulsion is desirable, to be applied with a spray pump or in the form of a dip. An emulsion of crude petroleum recommended by the U. S. Department of Agriculture, Bureau of Animal Industry,[1] is prepared as follows:

Hard soap	1 pound
Soft water	1 gal.
Beaumont crude petroleum	4 gal.

This formula is sufficient to make five gallons of 80 per cent stock emulsion. For use this must be diluted with water to a 20 to 25 per cent emulsion, or one part stock emulsion to three or two and one-fifth parts of water.

To prepare the stock the soap should be "shaved up and placed in a kettle or caldron containing the required amount of water. The water should be brought to a boil and stirred until the soap is entirely dissolved. Enough water should be added to make up for the loss by evaporation during this process. The soap solution and the required amount of oil are then placed in a barrel or some other convenient receptacle and mixed. The mixing may be effected by the use of a spray pump, pumping the mixture through and through the pump until the emulsion is formed. Only rain or soft water should be used for diluting." If hard water is used, it should be softened by adding sodium carbonate (sal soda), ¼ pound to every 5 gallons of water used. The

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[1] Graybill, H. W., 1912. Methods of exterminating the Texas fever tick. U. S. Dept. of Agr., Farmers' Bull. No. 498.

Beaumont oil recommended has a "specific gravity ranging from 22½° to 24½° Beaumé, containing 1¼ to 1½ per cent sulphur, and 40 per cent of the bulk of which boils between 200° and 300° C."

Arsenical dips are now more widely used than any other kind. The U. S. Department of Agriculture, Bureau of Animal Industry (Graybill, 1912, *loc. cit.*), recommends the following formula:

Sodium carbonate (sal soda)................	24 pounds
Arsenic trioxid (white arsenic).............	8 pounds
Pine tar....................................	1 gal.
Water sufficient to make 500 gallons.	

The following directions are given by the Bureau of Animal Industry for the preparation and use of the above arsenical dip:

> "In preparing the dip a large caldron or galvanized tank is required for heating the water in which to dissolve the chemicals. Twenty-five gallons of water should be placed in the caldron or tank and brought to a boil. The amount of sodium carbonate indicated in the formula is then added and dissolved by stirring. When this is accomplished, the required amount of arsenic is added and dissolved in a similar manner. The fire is then drawn, and the solution permitted to cool to 140° F., or this process may be hastened by the addition of cold water. The pine tar is then added slowly in a thin stream and thoroughly mixed with the solution by constant stirring. This solution should be diluted at once to 500 gallons.
>
> "The caldron or tank and utensils used in preparing the dip should be kept free from grease or oil, as small quantities of these may envelop particles of arsenic and prevent or hinder the solution of the arsenic. It should also be borne in mind that when hard water is used in the preparation of the dip the dissolving of the sodium carbonate (sal soda) in the boiling water results in the formation of a fine white or gray insoluble powder or precipitate of lime salts which may be taken for undissolved arsenic, and thus lead to the belief that all of the arsenic has not gone into solution.
>
> "The arsenical solution when prepared according to the above method should be diluted as soon as the pine tar has been added, in order that the tar may become properly emulsified. In the concentrated solution the tar tends to separate out, especially when the solution becomes cold, and collect in a layer at the bottom of the container. Even when the plan of immediately diluting the solution is followed a satisfactory emulsion is not always obtained, and some of the tar may separate and go to the bottom of the vat.
>
> "If, however, the acids present in the tar are neutralized by the use of concentrated lye, a good emulsion of the tar in the diluted dip may be obtained.[1] The neutralization is effected by dissolving 1 pound of concentrated lye in a quart of water for every gallon of tar to be used and adding this solution to the tar, stirring thoroughly. When the acids of the tar have been properly neutralized the resulting mixture should be a bright, thick fluid of a dark brown color. Whether the acids have been neutralized or not may be determined by taking a small quantity of the tar on the blade of a pocket knife or on a sliver of wood and stirring it in a

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[1] This method of emulsifying the tar has been suggested by the Biochemic Division of the Bureau of Animal Industry

glass of water. If the acids have been neutralized, the tar will mix uniformly with the water; whereas, if they have not been neutralized, the tar will float about in the water in the form of various-sized globules that will settle to the bottom when the agitation of the water ceases. For all ordinary grades of tar one pound of lye to the gallon will be ample to effect neutralization, but if on testing it is found that this amount has not been sufficient, it will be necessary to add more lye solution, about a pint at a time for each gallon, until the test shows that the acids have been neutralized. The neutralized tar should be added to the diluted arsenical dip and not to the concentrated solution, with which it will not mix satisfactorily. When the neutralized tar is used the vat should be filled with diluted arsenic-soda solution prepared in the usual way. The required amount of neutralized tar, diluted with two to three times its volume of water, should then be added to the solution in the vat and thoroughly mixed with the same by stirring.

"Before filling a vat the capacity, at the depth to which it is necessary to fill it for dipping, if not known, should be calculated, and for future convenience the water line should be plainly marked at some point on the wall of the vat. Unless this is done it will be necessary either to calculate the amount of water in the vat each time it is filled or measure it as it is placed in the vat, both of which procedures will consume considerable unnecessary time. The most convenient way to get the water into the vat is to conduct it through pipes, either directly from a pump or from an elevated tank used for storing water for farm purposes. Frequently, however, it is not possible to bring the water to the vat through pipes, and it becomes necessary to resort to the laborious process of hauling it in barrels on wagons or sleds.

"In case the pine tar is added to the concentrated solution when it is made, in which case, as already stated, it is necessary to dilute the solution at once, the vat should be partly filled with water and then the arsenical solution added as it is made. For example, if the vat holds 2000 gallons, about 1500 gallons of water should be placed in the vat, then four times the amount of solution for making 500 gallons of dip should be prepared and mixed with the water, after which the vat should be filled to the 2000-gallon mark. Within certain limits it is immaterial just how much water is added at first, provided, of course, ample allowance is made for the volume of the concentrated dip so that when it is added the dip line will not come above the mark to which the vat is to be filled.

"The capacity of the vat at a depth of 5 feet 3 inches is 1470 gallons. In order to fill it to that depth with dip it will be necessary to prepare two batches of concentrated dip, each containing the ingredients necessary for making 500 gallons of diluted dip, and a third batch containing 7 pounds, 9 ounces of arsenic and 22 pounds, 3 ounces of sodium carbonate in case 8 pounds of arsenic are being used to the 500 gallons, or 9 pounds, 7 ounces of arsenic and 22 pounds, 8 ounces of sodium carbonate in case 10 pounds of arsenic are being used to the 500 gallons.

"The arsenical dip may be left in the vat and used repeatedly, replenishing it with the proper quantities of water and stock solution when necessary. When, however, the dip becomes filthy through the addition of manure and dirt carried in by the cattle, the vat should be emptied, cleaned, and filled with fresh fluid. The frequency with which this should be done must be left to the owner, as the condition of the dip at any period after it has been made depends on a variety of conditions, such as the number of cattle dipped, and the frequency of the dippings, etc. Even though the dip may not become very filthy, its efficiency decreases somewhat on standing, owing to gradual oxidation of the arsenic. It is therefore advisable to recharge the vat at intervals irrespective of the condition of the dip to cleanliness."

"S-B" (self-boiled) Arsenic Dip.[1]—A homemade arsenic dip known as the S-B dip calls for two stock solutions, arsenic stock and tar stock which must not be mixed except in the diluted dipping bath. Before starting the following materials should be ready to hand:

	Pounds
Caustic soda	4
White arsenic	10
Sal-soda crystals	10

"There should be also some means for heating the solution in case, as sometimes happens because of impure materials, lack of skill, or some unforeseen circumstance, the heat created by mixing the materials should be insufficient to dissolve all the arsenic.

"In a 5-gallon kettle or metal pail (use a seamless pail stamped from a single sheet of iron) place the four pounds of caustic soda, add one gallon of cold water, and stir with a stick until the caustic soda is practically all dissolved. Without delay begin adding the white arsenic, in portions of a pound or two at a time, as fast as it can be dissolved without causing the solution to boil, stirring all the time. If the liquid begins to boil, stop stirring and let it cool slightly before adding more arsenic. The secret of success is to work the arsenic in fast enough to keep the solution very hot—nearly but not quite at the boiling point. The result should be a clear solution, except for dirt. If the liquid persistently remains muddy or milky, it may be because the operation has been conducted so fast that much water has been boiled out and sodium arsenate is beginning to crystallize, so add another gallon of water and stir. If the solution does not then clear up, the caustic soda must have been very low grade, and the undissolved substance must be arsenic. In that case, put the kettle over the fire, heat nearly, but not quite, to boiling, and stir. As soon as the solution of arsenic is complete, dilute to about four gallons, add the sodium carbonate, and stir until dissolved.

"*Cautions:* It is necessary to avoid splashing. Hence never work hurriedly; stir deliberately and regularly; do not dump in the arsenic and sal soda, but carefully slide them in from a grocer's scoop held close to the side of the pail and to the surface of the liquid. Perform the whole operation in a well-ventilated place and avoid inhaling steam.

"After the solution has become cold add water to make it exactly five gallons, mix well, let settle, and draw off into containers which can be tightly corked or otherwise closed. Jugs or demijohns are best, but tin cans will serve if occasionally inspected for leaks which may occur after a time through the action of the solution upon the solder of the can.

"In a large metal pail dissolve three-fourths of a pound of caustic soda in one quart of water, add one gallon of pine tar, and stir thoroughly with a wooden paddle until the mixture, which at first looks streaked and muddy, brightens to a uniform, thick fluid somewhat resembling molasses. Test it by letting about a teaspoonful drip from the paddle into a glass of water (a glass fruit jar or a wide-mouth bottle will do) and stirring thoroughly with a sliver of wood. It should mix perfectly with the water. Globules of tar which can be seen by looking at the glass from underneath and which can not be blended with the water by repeated stirring indicate that more caustic-soda solution is needed. In that case make up more caustic-soda solution of the same strength and add it, not more than a pint at a time, with thorough stirring, until the desired effect is produced.

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[1] U. S. Farmers' Bull. 1057.

"If an appropriate glass vessel for making the test is not at hand, take a little of the mixture between the fingers, then dip the fingers under water and try to rub off the tar. It should leave the fingers perfectly clean after a little rubbing with water. If an oily coating remains, more caustic-soda solution is needed. Such an extra addition of caustic soda will be required only in case of a very low-grade chemical or a very highly acid tar. The tar stock should be kept in closed containers, such as a pail with a friction top.

"The quantity of S-B arsenic stock or of tar stock made in one operation can be varied as desired, provided the above-given proportions of the ingredients are adhered to. But one should attempt to work the S-B formula on a larger scale only after skill and experience have been acquired."

Precautions.—From the time the arsenic is purchased to the final disposal of the old dip, great care should be exercised in storing, handling and using the same owing to the very poisonous nature of the chemical. "Cattle should always be watered a short time before they are dipped. After they emerge from the vat they should be kept on a draining floor until the dip ceases to run from their bodies; then they should be placed in a yard free of vegetation until they are entirely dry. If cattle are allowed to drain in places where pools of dip collect from which they may drink, or are turned at once on the pasture, where the dip will run from their bodies on the grass and other vegetation, serious losses are liable to result. Crowding the animals before they are dry should also be avoided, and they should not be driven any considerable distance within a week after dipping, especially in hot weather. If many repeated treatments are given, the cattle should not be treated oftener than every two weeks.

"In addition to properly protecting vats containing arsenical dip when not in use another precaution must be observed when vats are to be emptied for cleaning. The dip should not be poured or allowed to flow on land and vegetation to which cattle or other animals have access. The best plan is to run the dip into a pit properly protected by fences. The dip should also not be deposited where it may be carried by seepage into wells or springs which supply water used on the farm."

Procedure.—After having exercised the precaution of watering them, the cattle to be dipped are driven from a pen one by one into the chute and thence into the dip (Fig. 193). The plunge is likely to wet the animal all over, but a second plunge of the head into the dip near the middle of the vat by means of a forked stick is advised so that the head is really plunged under twice in passage through the dip. After drying, the cattle should be driven on to a tick-free pasture and

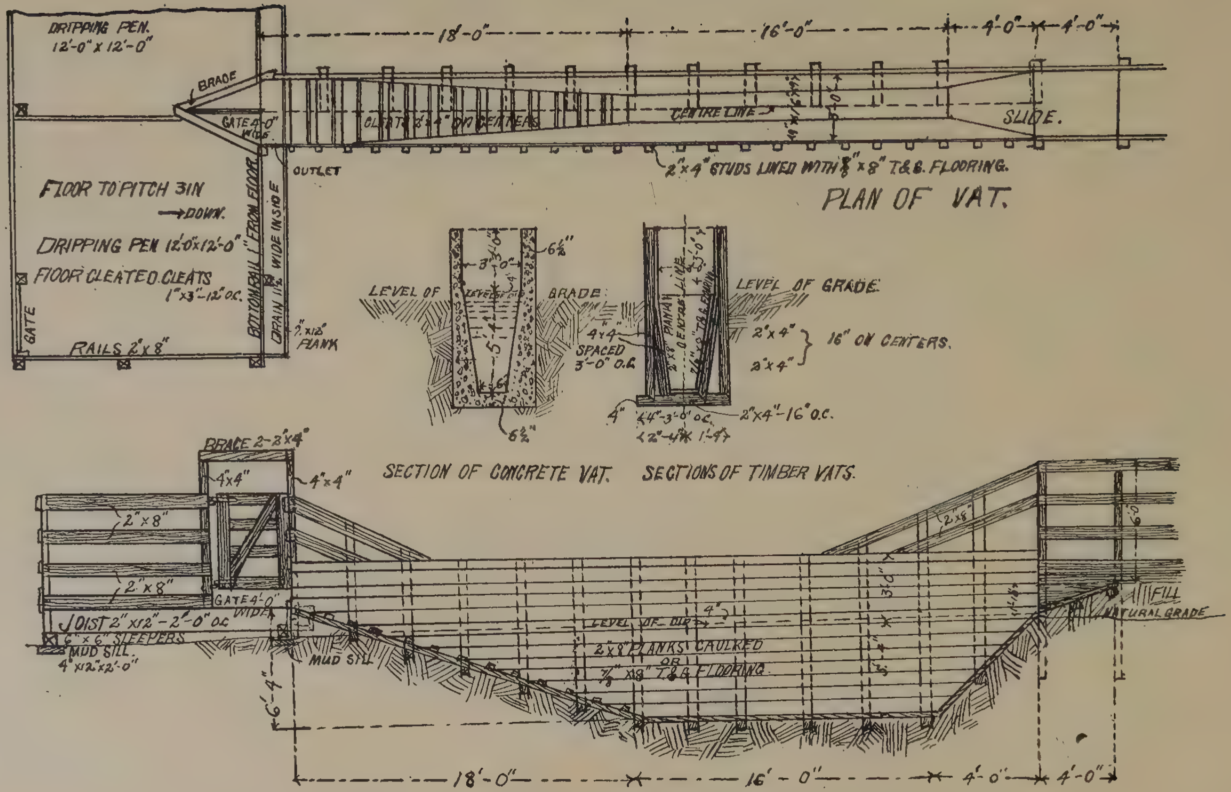

FIG. 193.—Drawings for wood or concrete dipping vat. (Redrawn after Graybill.)

the process repeated in from seven to ten days in order to destroy all ticks which may have escaped the action of the first dipping.

Pasture Rotation.—Exterminating ticks by pasture rotation is based on the time required to kill the ticks by starvation. Inasmuch as the longevity of ticks depends on moisture and temperature mainly, local conditions affecting the same must be taken into consideration. Cold and moisture prolong life, while dryness and heat shorten the same.

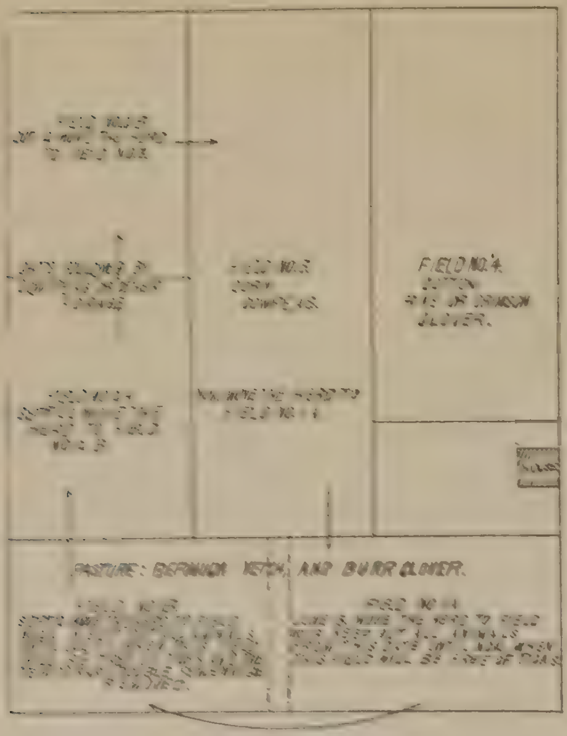

FIG. 194.—Plan for freeing cattle and pastures from ticks by rotation, requiring four and one half months. (Redrawn after Graybill.)

In pasture rotation the cattle are kept off of a given pasture for a given length of time, after which they are moved to a third area, etc., until all ticks have matured and have dropped from the cattle and have died from starvation on the earlier plots. Thus a field should be divided into three or more plots each separated by means of two fences about fifteen feet apart to reduce the opportunity of ticks to crawl from one plot to the other.

Various plans requiring from four and a half to eight months have been devised to free both cattle and pasture from ticks. Thus a plan requiring four and one half months is described by Graybill (1912, *loc. cit.*) (Fig. 194). He advises dividing the pasture in the middle by two lines of temporary fence fifteen feet apart. This is to be done some time in the spring. The herd is first kept in field No. 1A, and is then removed, on June 15, to field No. 1B, and on September 1 to field No. 2A. The cattle must remain twenty days on fields 2A, 2B, and 3. At the end of this time, which would be November 1, all the ticks will have dropped and the herd is returned to field No. 1A, which has become free from ticks in the meantime. Field No. 1B becomes free from ticks July 1 of the following year, when the double fence between 1A and 1B may be removed and the cattle may then (and not before) graze over both fields. By August 1 the entire farm will be free from ticks.

Graybill advises as above that double fences be built between all the fields, when practicable, in order to prevent ticks from getting from one field to another. In place of the extra line of fence the next best thing would be to "throw up several furrows with a plow on each side of the dividing fences." If streams run through the farm or the slope of the land is considerable, so that ticks may be washed from field to field, he advises arranging the fields so that drainage is from field No. 1A to No. 1B, and from No. 3 toward fields Nos. 2A and 2B.

African coast fever, also known as Rhodesian red water, occurs along the east coast of Africa, including Rhodesia and the Transvaal. The mortality is said to range close to 90 per cent. The causative organism is *Theileria parva* (Theiler). The symptoms of the disease, according to Robertson,[1] are described as follows:

> "These are neither very definite nor characteristic. The disease runs its course in from twelve to fifteen days, dating from the time the animal is first noticed sick. The temperature is high, 106° to 107° F. There is running from the eyes and nose, and symptoms of pain in the abdomen. Purging and diarrhea are frequently seen. In the later stages the dung may contain blood and be dark in color. The animal's brain usually becomes affected before death, which is preceded by stupor and coma. If the lungs become involved there is great distress in breathing, accompanied by a short cough."

Lounsbury's [2] experiments demonstrate that African coast fever may be transmitted to susceptible cattle from actually sick ones through the medium of five species of ticks of the genus Rhipicephalus, namely, *R. appendiculatus* Neum., *R. evertsi* Neum., *R. simus* Koch, *R. capensis* Koch, and *R. nitens* (Neum.). He succeeded in transmitting the disease from twelve sick animals to thirty-five healthy ones by means of ticks. The infection was taken by ticks in one stage of the life history and transmitted in the next following stage. A dozen or more ticks were usually applied in each case; however, he succeeded in infecting an animal with one tick alone and in another case by two ticks. The ticks are believed to be in constant readiness to transmit infection. The incubation period was found to average 13½ days and ranged from 9 to 19 days. While the duration of the cases averaged 12 days, it was found that few of the animals appeared seriously ill until a few days before death, an important factor in the dissemination of the disease in the veldt during the time that the infective animal is active.

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[1] Robertson, W., 1904. African coast fever. Cape of Good Hope, Dept. of Agr. Bull. No. 18.

[2] Lounsbury, Chas. P., 1906. Ticks and African coast fever. Agric. Journ. of the Cape of Good Hope, Vol. XXVIII, No. 5, pp. 634-654.

The parasite of the disease is not transmitted in a so-called hereditary manner from the adult female to the larvæ through the eggs as in Texas fever, but only from one stage of the tick to another, i.e., if the seed ticks are fed on an infected animal the nymphs are infective, or if the nymphs are fed on an infected animal the adults are infective. Of the above mentioned ticks, *Rhipicephalus appendiculatus* is the common carrier.

Spotted Fever.—Spotted fever has been known in the Bitter Root Valley of Montana (U. S. A.) since 1872,[1] also known as "tick fever," "black fever," "blue disease," and "black measles." The most characteristic and constant symptom is the eruption which appears about the second to the fifth day on the wrists, ankles and back, later spreading to all parts of the body and lasting from a few days (8 to 21) to several months:

> "These spots are petechial and not raised; at first they are rose-colored and disappear momentarily upon pressure; but later they become permanent and assume a dark blue or purplish color; they may coalesce and give a mottled or marbled appearance to the skin; they may or may not be tender to the touch. . . . The fever develops rapidly, and may register 102° to 104° or 105° F., when the patient takes to bed. It gradually reaches its maximum in two to seven days, when it ordinarily registers 103° to 106°.
>
> "Both sexes and all ages are subject to the disease, but it is more common in males from 21 to 40, and in females from 11 to 40 years of age, than at other times of life. . . . A lethality of 70.5 per cent was shown for 139 collated cases . . . 100 per cent for all patients over 60 years old. So far as one could judge occupation seems to play a rôle, for a very large percentage of the patients are on farms or are connected with the lumbering industry" (Stiles, 1905, *loc. cit.*).

In Idaho a mild type of the disease exists, with a mortality of about 1 to 3 per cent according to Stiles and from 5 to 7 per cent according to Hunter and Bishopp.

In a report on spotted fever in California covering a period of from 1903 to 1916, Kelly[2] states, "that of the six cases in Modoc one died, and of the thirty-two in Lassen five terminated fatally, giving a mortality of sixteen per cent. Thus the type of disease in California is apparently not so severe as in the Bitter Root Valley of Montana, nor as light as in Idaho."

After years of search the causative organism was discovered by Wolbach[3] in 1919 and named *Dermacentroxinus rickettsi* Wolbach and a long step has been taken toward a better understanding of the disease. In the investigation of this disease two physicians have lost their lives directly by the same, namely, Thomas B. McClintic and Arthur H. McCray, and as a part of his study of spotted fever in comparing it with typhus fever, Howard T. Ricketts lost his by the latter.

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[1] Stiles, Ch. Wardell, 1905. A zoölogical investigation into the cause, transmission and source of Rocky Mountain "spotted fever." Treasury Dept. Public Health and Marine Hospital Service of the United States. Hygiene Lab. Bull. No. 20, 121 pp.

[2] Kelly, F. L., 1916. Rocky Mountain Spotted Fever—its prevalence and distribution in Modoc and Lassen Counties, California—a preliminary report. Cal. State Journ. of Med. (Oct., 1916).

[3] Wolbach, S. B., 1919. Studies on Rocky Mountain Spotted Fever. Journ. Med. Res., Vol. XLI, No. 1, pp. 1-197.

Tick Transmission of Spotted Fever.—After a preliminary investigation Wilson and Chowning[1] in 1902 advanced for the first time the theory that a tick ("wood tick") acts as the natural vector of the disease. According to Ricketts (in 48th Biennial Rept. Montana State Board of Health, p. 106) as recorded by Hunter and Bishopp[2] "the first experiments which resulted in the proof of the transmission of spotted fever by a tick were conducted by Drs. McCalla and Brereton of Boise, Idaho, in 1905. In these experiments a tick which was found attached to a spotted fever patient was removed and allowed to bite a healthy person. In eight days this person developed a typical case of spotted fever. The experiment was continued by allowing the same tick to bite a second person. In this case again a typical case of spotted fever resulted."

The famous experiments of Dr. H. T. Ricketts began in April, 1906. The more important published work of this lamented investigator has been brought together in a memorial volume[3] from which the following summary is made of his reports on spotted fever. First of all it was shown that the disease could be transmitted to guinea-pigs by direct inoculation and that the duration of the fever and cutaneous phenomena resembled very closely the conditions as observed in humans. Hence, knowing the susceptibility of this species, it was used for further experimentation.

On June 19, 1906, a small female tick was placed at the base of the ear of a guinea-pig inoculated intraperitoneally June 11 with 3 cc. of defibrinated blood of a spotted fever patient. The tick fed for two days on this animal and was then removed and kept for two days in a pill box and on June 23 placed at the base of the ear of a healthy guinea-pig, the former animal dying on the same day with characteristic symptoms. On June 28 the second guinea-pig showed a decided rise in temperature, which continued high until July 5 and became normal on July 7. Proper controls were conducted and two guinea-pigs which were in the same cage with the tick-bitten guinea-pig for two weeks did not become infected, indicating that mere association did not result in contracting the disease.

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[1] Wilson, Louis B., and Chowning, William M., 1902. The so-called "spotted fever" of the Rocky Mountains. A preliminary report to the Montana State Board of Health. Journ. Amer. Med. Assoc., Vol. 39, No. 3, pp. 131-136.

[2] Hunter, W. D., and Bishopp, F. C., 1911. The Rocky Mountain spotted fever tick. U. S. Dept. of Agric., Bur. of Ento. Bull. 105, 47 pp.

[3] Ricketts, H. T., 1911. Contributions to Medical Science. The University of Chicago Press. 497 pp. (See pp. 278-450.)

In addition to many other successful experiments during the following year Ricketts found that the disease can be transmitted by the male as well as by the female tick and that "one attack of the disease establishes a rather high degree of immunity to subsequent inoculation." Furthermore a collection of ticks taken in the field transmitted the disease to a guinea-pig in the laboratory, indicating the fact that infective ticks occur in nature in probably small numbers.

It was also ascertained that "the disease may be acquired and transmitted . . . by the tick during any of the active stages . . . and that the larvæ of an infected female are in some instances infective. . . . The disease probably is transferred through the salivary secretion of the tick, since the salivary glands of the infected adult contain the virus.'" The transmission is believed to be "biological rather than purely mechanical."

Experiments conducted by Moore (Ricketts, 1911, *loc. cit.*, pp. 428-436) show that the "minimum duration of feeding necessary for a tick to infect a guinea-pig was one hour and forty-five minutes. The average time necessary seems to be about ten hours, while twenty hours were almost constantly infective." Maver (see Ricketts, 1911, *loc. cit.*, pp. 440-444) in a series with other species of ticks found that spotted fever can be transmitted from infected to normal guinea-pigs by *Dermacentor variabilis* (Say), *Dermacentor marginatus* Banks and *Amblyomma americanum* Koch in addition to *Dermacentor venustus* Banks.

Rocky Mountain Spotted Fever Tick.—The spotted fever tick, *Dermacentor venustus* Banks = *Dermacentor andersoni* Stiles (Fig. 195), possesses the general characters of the genus Dermacentor, viz.: "Usually ornate, with eyes and festoons; with short, broad or moderate palps and *basis capituli* rectangular dorsally. In some species coxæ I to IV of the male increase progressively in size; in all species coxa IV is much the largest; the male, moreover, shows no ventral plates or shields. Coxa I bifid in both sexes. Spiracles sub-oval or comma-shaped" (Nuttall, 1911, *loc. cit.*).

The species is described by Banks,[1] viz.:

"Male—red brown, marked with white, but not so extensively as in *D. occidentalis*, usually but little white on the middle posterior region; legs paler red-brown, tips of joints whitish. Capitulum quite broad, its posterior angles only slightly produced; palpi very short and broad, not as long as width of capitulum. Dorsum about one and two-thirds or one and three-fourths times as long as broad, with many, not very large, punctures; lateral furrows distinct. Legs of moderate size, hind pair plainly larger and heavier, and with the teeth below distinct. Coxæ armed as usual, the coxa IV nearly twice as wide at base as long. Stigmal plate with a rather narrow dorsal prolongation, with large granules on the main part and minute ones on the prolongation.

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[1] Banks, Nathan, 1908. A Revision of the Ixodoidea, or Ticks, of the United States. U. S. Dept. of Agr. Bur. of Ento. Technical Series, No. 15, 61 pp.

"Length of male, 3.5 to 5 mm.

"Female—Capitulum and legs reddish brown, the latter with tips of joints whitish; shield mostly covered with white, abdomen red-brown. Capitulum rather broad, posterior angles but little produced, the porose areas rather large, egg-shaped, and quite close together; palpi shorter than width of capitulum. Shield as broad as long, broadest slightly before the middle, and rather pointed behind, with numerous, not very large punctures. Legs of moderate size, the coxæ armed as usual. The stigmal plate has a rather narrow dorsal prolongation, with large granules on the main part, and small ones on the prolongation.

"Length of female shield, 2 mm."

Life History and Habits of Spotted Fever Tick.—The most complete and satisfactory study of the habits and life history of this species has been made by Hunter and Bishopp (*loc. cit.*), from whose work the following account is taken. The winter is passed by the ticks as unengorged males, females and nymphs. They begin attacking their warm-blooded hosts, including man, about March 15 and continue so doing to about July 15. During this period the female deposits eggs. The overwintering nymphs transform to adults during the summer and autumn and pass the winter in an unengorged condition, thus requiring about two years for their development. As much as three years may be required for complete development under unfavorable conditions.

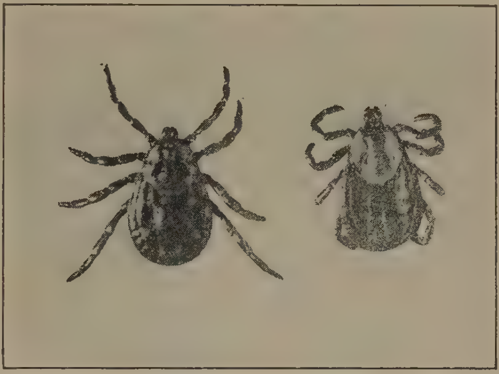

Fig. 195.—The spotted fever tick, *Dermacentor venustus;* male (left), unengorged female (right). × 3.5.

The engorged females after being fertilized drop from the host animal and deposit about 4,000 eggs within 30 days, beginning to deposit as early as the 7th day after dropping. The eggs are ovoid, brownish in color and about one thirty-eighth of an inch long. The incubation period ranges from 34 to 51 days in the Bitter Root Valley (15 to 41 days at Dallas, Texas). The newly emerged hexapod seed ticks shortly after hatching crawl up blades of grass or other objects and await the coming of a host, usually one of the smaller species of rodents, e.g., ground squirrels, chipmunks, woodchucks, pine squirrels and wood rats.

After attaching to the host the larvæ become filled with blood in from 3 to 8 days, after which they drop off and molt in from 6 to 21 days, emerging from this stage with eight legs,—a nymph. Nymphs emerging from the larval or seed tick stage late in summer or autumn pass the winter as nymphs, others find a second host, either a small mammal or less commonly a larger wild or domesticated animal. The feeding period requires from 4 to 9 days, when the engorged nymphs drop to the ground and in 12 to 16 days and over, molt for the second time, emerging as adults.

The adults now by preference attach themselves to larger domesticated animals. After feeding about 4 days the males search their mates, mating on the host animal, and after 8 to 14 days after attachment the engorged females drop to the ground and deposit their eggs in some protected place near by.

It is said that the tick may live from 2 to 6 years after it hatches from the egg, although the average is probably not more than 3 or 4 years.[1]

The fully engorged females are "about one half inch long by one third inch wide by one fourth inch thick. On account of the enormous distention of the back part of the body of the female, the legs and head are rendered inconspicuous. A close examination, however, will show the white shield on the back just behind the 'head.'" The males are about the same size as the females before engorgement, and have the shield (scutum) covering the entire back, whereas in the female the shield is much smaller (Fig. 195).

Longevity.—Hunter and Bishopp (1911, *loc. cit.*) have "found that all unfed seed ticks hatching from a mass of eggs usually die within one month after the first eggs hatch. In one instance a period of 117 days elapsed between the beginning of hatching of the eggs and the death of the last seed tick. (A later record by these workers exceeded 317 days.) Unfed nymphs have been found to survive a period of one year and eleven days, and adults collected on vegetation during the spring months may survive for a period of 413 days without food."

Distribution.—Bishopp[2] states that the northern part of the Rocky Mountain region of the United States is the territory principally infested, but the river valleys and sagebrush plains in the west are more or less heavily infested,—Idaho, Wyoming, Montana, parts of Utah, Colorado, Nevada, Oregon, Washington, California and southern British Columbia being involved. The species is believed to occur in greatest numbers between 3,000 and 5,000 feet elevation.

Control of Spotted Fever Tick.—Knowing that the most important agent, if not the sole agent under natural conditions, in the dissemination of spotted fever is *Dermacentor venustus*, it becomes evident at once that the control of this tick is essential to the control of the disease.

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[1] Parker, R. R., 1921. The Control of Rocky Mountain Spotted Fever in the Bitter Root Valley. The Montana State Board of Entomology Circ. 1 (revised), 20 pp.

[2] Bishopp, F. C., 1911. The Distribution of the Rocky Mountain Spotted-fever Tick. U. S. Dept. of Agr., Bur. of Ento. Circ. No. 136.

The most significant step toward the control of spotted fever in Montana was taken by the legislature of that state in 1913, when a bill was passed creating a State Board of Entomology, with authority to act, and appropriating funds for its use.

The main control methods employed in Montana according to Parker (*loc. cit.*) are: (1) killing rodents that harbor the larvæ and nymphal ticks, directed chiefly against the Columbian ground squirrel and consists of the use of strychnin- and saccharin-coated crushed oats; (2) destruction and prevention of ticks engorging on domestic animals by dipping, hand-picking from dairy animals, work horses and such animals as it may be possible to handle in this way, and control of grazing on infested territory; and (3) clearing and immediate cultivation, and burning.

Other Tick Borne Diseases.—At least two types of piroplasmoses are found in horses and mules, namely true equine piroplasmosis, traceable to *Babesia caballi* (Nuttall), occurring in Russia, Transcaucasia and probably Siberia, and secondly a similar though distinct disease traceable to *Nuttallia equi* (Laveran) occurring in Transcaucasia, Italy, Africa, India and South America (Brazil). The former is transmitted by *Dermacentor reticulatus* while the latter is transmitted by *Rhipicephalus evertsi.*

Ovine piroplasmosis traceable to *Babesia ovis* (Babes) occurs in sheep in Transcaucasia, Roumania, Turkey and probably also in northern Africa. The disease is carried by the tick, *Rhipicephalus bursa.*

Canine piroplasmosis, also known as "malignant jaundice" of dogs, is prevalent in Europe, Asia and Africa. The causative organism is *Babesia canis* Piana and Galli-Valerio and the carrier is *Rhipicephalus sanguineus* Latr. in India, Europe and North Africa; *Hæmaphysalis leachi* and *Dermacentor reticulatus* are the carriers in other parts of Africa. Brumpt and Larrousse [1] have shown that *Dermacentor venustus* can carry the disease.

Heart water due to an undetermined, probably ultramicroscopic organism,[2] is a dreaded disease of South African sheep, goats and cattle. It is carried by *Amblyomma hebræum* Koch, which is said to lay up to 18,500 eggs in 8 to 11 days at 30° C. (Nuttall). It is a three-host tick and under optimum conditions in the laboratory has a life cycle (egg to egg) of 171 days (Nuttall).

Tick Paralysis.—A very striking form of paralysis induced by the bite of *Dermacentor venustus* has been reported[1] as occurring in both sheep and man (children), also in other animals (dog and rabbit), in British Columbia and Montana. In lambs the paralysis develops gradually, beginning with a staggering gait, bumping against obstacles and occasionally falling, finally failing to rise. The attack is usually of short duration but may persist for long periods and may terminate fatally. The symptoms appear in from six to seven days after the ticks have become attached. It is believed that the disease is caused by the inoculation of a toxin from the tick. It has also been observed that the ticks attach themselves by preference along the spinal column of the host, and at the nape of the neck in man.

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[1] Brumpt, E., et Larrousse, F., 1922. Transmission de la Piroplasmose canine française par le *Dermacentor venustus.* Bull. de la Soc. de Path. Exot., Tome XV, No. 7, pp. 540-545.

[2] Nuttall, G. H. F., 1916. Ticks of the Belgian Congo and the diseases they carry. Bull. Ent. Res., Vol. VI, Pt. IV, pp. 313-352.

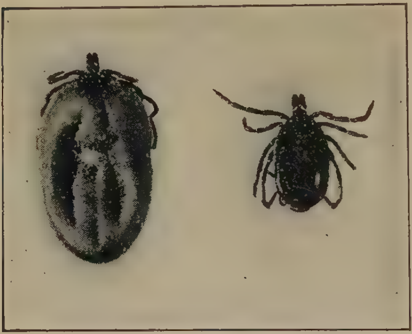

Fig. 196.—A common deer and cattle tick of California, *Ixodes ricinus* var. *californicus*; female (left), male (right). × 3.5.

Other Ixodine Ticks. — Over forty species of ticks (mostly Ixodine) are known to occur in the United States alone, and many other species occur in the tropics. For the disease-bearing and venomous species it may be said that a single individual may be of great importance, while the economic importance of the innocuous species depends on relative abundance. The most widely distributed and abundant genera are Ixodes and Dermacentor. *Ixodes ricinus* Linn., commonly called the "castor bean tick," is found in Europe, America, Asia and Africa, and attacks many species of warm-blooded animals. *Ixodes ricinus* var. *californicus* Banks (Fig. 196) is commonly found in California on the black-tailed deer, the bobcat and other species of wild animals, also frequently and abundantly on cattle. *Ixodes hexagonus* Leach occurs on squirrels in California.

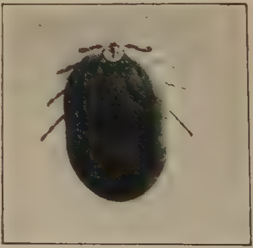

Fig. 197.—Western dog or wood tick, *Dermacentor occidentalis*. × 2.5.

The common "dog tick" or "wood tick" also attacks many species of warm-blooded animals, among them horses, cattle, dogs and man. When abundant these species are of considerable importance. In the eastern part of the United States *Dermacentor variabilis* Say is the most common, while along the Pacific Coast it is largely replaced by *Dermacentor occidentalis* Neumann (Fig. 197). *Dermacentor parumapterus* Neum. commonly occurs on jackrabbits in California. In the southern part of the United

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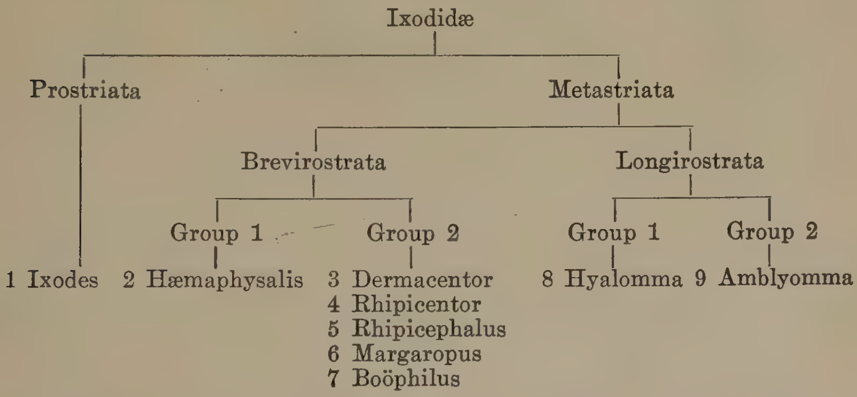
[1] Hadwen, Seymour, 1913. On "Tick paralysis" in sheep and man following bites of *Dermacentor venustus*. Parasitology, Vol. VI, No. 3, pp. 293-297, with 2 plates.

States, particularly Texas and Louisiana, the "lone star tick," *Amblyomma americanum* Linn. (Fig. 198) is very common. The "rabbit tick" *Hæmaphysalis leporis* = *H. palustris* (Packard), is a widely distributed and abundant species on rabbits, while *Rhipicephalus sanguineus* Latreille is known as the "brown dog tick" and is almost a cosmopolitan species.

Nuttall (1911, *loc. cit.*) includes nine genera in the family Ixodidæ, namely:—Ixodes, Hæmaphysalis, Dermacentor, Rhipicentor, Rhipicephalus, Margaropus, Boöphilus, Hyalomma and Amblyomma (Aponomma).

> "Ixodes is clearly marked off from the other genera by a number of characteristics, of which the most striking are the anal groove surrounding the anus *in front* (Prostriata) and the absence of festoons. The remaining genera fall naturally into two divisions: the one characterized by a comparatively short, and the other by a comparatively long, capitulum."

Nuttall further arranges these as follows:



"**Ixodes**: inornate; without eyes and without festoons; spiracles round or oval; palpi and basis capituli of variable form; coxæ either unarmed, trenchant, spurred or bifid; tarsi without spurs. Sexual dimorphism pronounced, especially with regard to the capitulum; in the male the venter is covered by non-salient plates; one pregenital, one median, one anal, two adanal and two epimeral plates."

"**Hæmaphysalis**: inornate, without eyes but with festoons; with usually short conical palpi whose second articles project laterally beyond the basis capituli, which is rectangular dorsally. With dorsal process on first trochanter. Usually of small size and but slightly chitinized. Sexual dimorphism slight. The male shows no ventral plates or shields. Spiracles in male usually ovoid or comma-shaped; in female rounded or ovoid."

"**Dermacentor**: usually ornate, with eyes and festoons; with short, broad or moderate palpi and basis capituli rectangular dorsally. In some species coxæ I to IV of the male increase progressively in size; in all species coxa IV is much the largest; the male, moreover, shows no ventral plates or shields. Coxa I bifid in both sexes. Spiracles suboval or comma-shaped."

"**Rhipicentor**: inornate, with eyes and festoons; with short palpi, with basis capituli hexagonal dorsally and having very prominent lateral angles. Coxa I bifid in both sexes. The male resembles *Rhipicephalus* dorsally, *Dermacentor* ventrally; coxa IV is much the largest; no ventral plates or shields; spiracles subtriangular (female) or comma-shaped (male)."

"**Rhipicephalus**: usually inornate, with eyes and festoons; with short palpi and basis capituli usually hexagonal dorsally. . . . Coxa I bifid. The male possesses a pair of adanal shields and usually a pair of accessory adanal; some males, when replete, show a caudal protrusion. Spiracles bluntly or elongate comma-shaped."

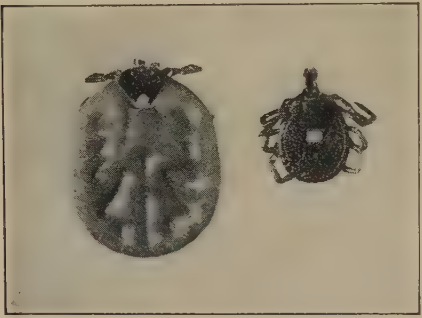


FIG. 198.—The lone star tick, *Amblyomma americanum*. × 3.5.

"**Margaropus**:[1] inornate, with eyes, but without festoons, with short palpi and capitulum intermediate between that of *Rhipicephalus* and *Boöphilus;* highly chitinized, the unfed adults of large size. The female with very small scutum. Coxæ conical, unarmed but for a small spine posteriorly on coxa I. The male with a median plate prolonged in two long spines projecting beyond and to either side of the anus; with coxæ similar to those of the female; legs increasing progressively in size from pair I to IV, the articles especially of leg-pair IV greatly swollen. When replete, the male shows a caudal protrusion. Anal groove obsolete. Spiracles rounded or short-oval in both sexes."

"**Boöphilus**: inornate, with eyes, but without festoons; with very short compressed palpi ridged dorsally and laterally; basis capituli hexagonal dorsally; slightly chitinized; the unfed adults of small size. Coxa I bifid. Anal groove obsolete in female, faintly indicated in male. The female with a small scutum; the male with adanal and accessory adanal shields. Spiracles rounded or oval in both sexes."

"**Hyalomma**: ornamentation absent or present, at times confined to the legs; with eyes, with or without festoons, with long palpi . . . and basis capituli subtriangular dorsally. The female approaching *Amblyomma*. The male with a pair of adanal shields, and with or without accessory adanal shields and two posterior abdominal protrusions capped by chitinized points. Coxa I bifid. Spiracles comma-shaped."

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[1] Does not include *Margaropus annulatus* = *Boöphilus annulatus*.

"**Amblyomma**: generally ornate, with eyes and with festoons. With long palpi, of which article 2 is specially long; basis capituli of variable form. The male without adanal shields, but small ventral plaques are occasionally present close to the festoons. Spiracles subtriangular or comma-shaped" (Nuttall).

The Argasine Ticks

Argas persicus (Oken) Fischer von Waldh. = *A. miniatus* Koch = *A. americanus* Packard, a cosmopolitan *fowl tick*, is one of the most important poultry parasites in existence (Fig. 199). Other than "fowl tick" this pest is commonly called "adobe tick," "tampan" or "blue bug." In color it varies from a light reddish brown to a dark brown, depending on the stage of engorgement. In size the obovate, flattened adults average about 8.5 mm. long by 5.5 mm. wide in the female, and 6.5 mm. long by 4.5 mm. wide in the male. When unengorged their thickness is about .75 mm., and when fully engorged may be nearly 3 mm. at the thickest part. The edges are always very thin even when engorged. The sexes are not easily distinguishable; the males are smaller, but may be as large as smaller female individuals and taper slightly more anteriorly, i.e., are more obovate. The genital orifice of the male is "half-moon shaped," while in the female it is "slit-like" and situated farther forward, i.e., immediately behind the capitulum. The capitulum has four long hairs, two hypostomal, and one near the articulation of each palp, all directed forwards. The palps are about twice as long as the hypostome, second article longest, the others equal in length. The hypostome has 6 or 7 fine denticles on each half distally, followed by stout teeth $\frac{2}{2}$, the numbers increasing to $\frac{3}{3}, \frac{4}{4}, \frac{5}{5}$, basally, the teeth decreasing in size, not attaining the external border nor extending beyond half the length of the hypostome (Nuttall).

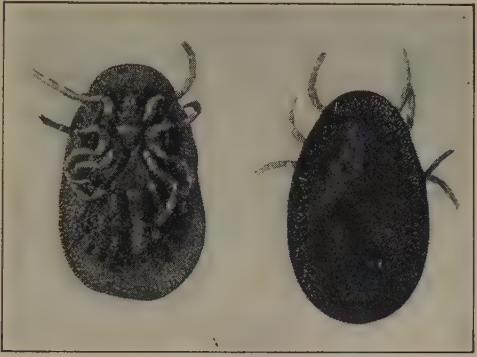

FIG. 199.—The poultry tick, *Argas* (*miniatus*) *persicus*, ventral and dorsal views. ×3.5.

Life History and Habits.—The nymphs and adults of *Argas persicus* are strikingly active at night, migrating long distances to find their host, and hiding in an inactive condition during the day. The writer has observed this pest in vast numbers hiding beneath the loose bark of the eucalyptus tree in California. Occasionally specimens are sent in with the inquiry, "are they parasites of the tree or do they attack roosting chickens, the chickens seem to do very poorly, yet we find nothing on them?" At night if one observes somewhat closely, one may see hordes of these ticks climbing up the sides of the chicken coop to the roosts and upon the fowls, filling up leisurely with blood and before daybreak departing for their hiding places. The females deposit their large reddish brown eggs in the crevices occupied during the day. The eggs are laid in masses of from 25 to 100, more or less, and there are usually several layings, with a total of several hundred per female. Egg deposition occurs very readily in almost any sort of receptacle in which the ticks may be kept for observation. Hatching takes place in from three to four weeks. The larvæ (Fig. 200) are six-legged and very active, attacking a host apparently as readily by day as by night. Once attached the larvæ feed for about five days, occasionally longer, remaining firmly attached during this time. When fully engorged they appear like little reddish globules, causing severe irritation. At the end of this feeding period the larvæ detach themselves, having become rather flattened in the meantime and then crawl away from the host, hiding in some convenient crevice near by. The larvæ molt in about a week, when the fourth pair of legs appears and they are now in the first nymphal stage, appearing like miniature adults. Nocturnal feeding now takes place and in ten or twelve days another molt occurs and the second nymphal stage is reached. Again the tick attaches itself, being now able to engorge itself in about an hour; again after the expiration of something over a week a third molt takes place and the adult stage is reached. The adults are able to engorge themselves in from 20 to 45 minutes.

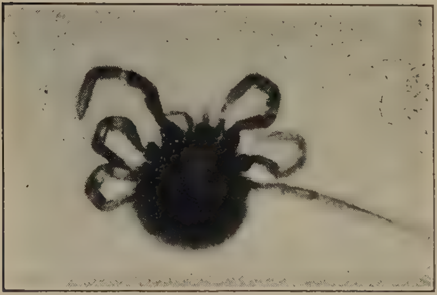

FIG. 200.—Larva of the poultry tick, *Argas* (*miniatus*) *persicus.* × 30.

Since eggs are deposited mainly during July in California, the adult stage may or may not be reached before the rainy season begins, and the overwintering stage may be in the second nymphal condition or as adults, appearing in pestiferous numbers early during the following summer. Hence there is ordinarily one generation of ticks per year under normal conditions. In the absence of a host this species manifests a striking longevity of a year and over (a little over two years according to Lounsbury).

Damage Done.—Each tick when engorging requires considerable blood to become replete, hence, when myriads of these parasites attack fowls great quantities of blood must be extracted. The writer has known of chickens being picked up under the roost in the morning with no apparent cause for death, and believes this to have been due directly to the work of ticks. Weakened and unthrifty condition of a flock may be traceable solely to ticks. Poultry suffering from ticks have dull, ragged plumage, suffer from diarrhea, are weak and lay poorly. Turkeys are most likely to suffer.

Fowl Spirochætosis.—A very fatal disease, known as "fowl spirochætosis," is traceable to *Spirochæta marchouxi* Nuttall = *Spirochæta gallinarum* Blanchard, occurring in India, Australia, Brazil, Egypt and Persia, and is no doubt very widely distributed. The disease attacks chickens, geese, turkeys, guinea fowls and other birds. The symptoms are described as follows:

> "The disease begins with diarrhea, followed by loss of appetite, the birds appearing somnolent; the feathers being ruffled and the comb pale. The birds cease to perch, lie down with the head resting upon the ground and death takes place during a convulsive attack. At times the disease runs a slower course, the legs become paralyzed, then the wings, and the bird grows thin and dies in eight to fifteen days. Recovery may take place, but it is rare after paralytic symptoms have appeared. At autopsy, during the acute period of the disease, the spleen appears much enlarged and the liver swollen with more or less fatty degeneration, at times the liver is dotted with focal necroses. In chronic cases both these organs may appear atrophied. The blood is fluid and dark. Spirochætes are plentiful in the blood until shortly before death, and they disappear as recovery sets in" (Nuttall).

Argas persicus has been proved to be the carrier by Marchoux and Salimbeni, Balfour, Nuttall and others. These investigators have found that when this tick sucks blood from an infected fowl the *spirochætes* multiply within the body of the same when kept at from 30° to 35° C. and are capable of transmitting the disease; but when they are kept at from 15° to 20° C. they fail to transmit it. However, if the ticks are later kept in the higher temperature they become infective. The *spirochætes* are transmitted by the bite and the ticks are said to be infective for six months or more. The incubation period in the fowl is from four to nine days.

Combating the Fowl Tick.—Henhouse roosts should be painted thoroughly with kerosene or carbolineum and put in position with the ends in cups of crude oil or tar or embedded in oil-soaked waste, or suspended by wires from the ceiling. Roost poles must be free from bark. All old nests and rubbish should be burned, and the interior, especially crevices, sprayed liberally with kerosene. Boiling water or steam may be used instead of kerosene. A repetition of the procedure once every five or six weeks during the tick season is recommended.

The use of considerable crude oil or creosote oil in and about the houses is very desirable. Fowls should not be permitted to roost in trees, because of the hiding places afforded the ticks beneath the bark, particularly when loose.

If the henhouses can be made tight, fumigation with sulphur is useful, using about five pounds per 1,000 cu. ft. of space.

For the treatment of fowls infested with larval ticks, an ointment of kerosene, lard and sulphur is advised.

Argas reflexus Fabr., commonly known as the "pigeon tick," differs from *A. persicus* in that the body narrows rather suddenly toward the anterior end and that the thin margin is flexed upward. The capitulum has "two long post-hypostomal hairs ventrally, directed forwards. Palps with articles sub-equal, the third the shortest, denticulated hairs dorsally. . . . Hypostome rounded terminally, some small denticles at the tip, followed by $\frac{2}{2}$ stout teeth merging into $\frac{3}{3}$ to $\frac{6}{6}$ progressively smaller teeth" (Nuttall).

Other species of Argas are *A. brumpti* Neumann, *A. vespertilionis* Latreille and *A. cucumerinus* Neumann.

Ornithodorus moubata Murray is the African relapsing fever tick (Fig. 201), sharing in general the characters of the genus Ornithodorus, viz.:

> "Body flat when unfed, but usually becoming very convex on distention. Anterior end more or less pointed and hood-like. Margin thick and not clearly defined, similar in structure to the rest of the integument, and generally disappearing on distention. Capitulum subterminal, its anterior portions often visible dorsally in the adult. Disks present or absent; but when present not arranged radially (see Argas). Certain fairly constant grooves and folds on the venter, namely, a coxal fold internal to the coxæ, a supracoxal fold external to the coxæ, a transverse pre-anal and a transverse post-anal groove or furrow, and a post-anal median groove. Eyes present or absent."

O. moubata occurs only in Africa, is an eyeless species with a specific arrangement of the "humps" on the protarsus of the first pair of legs, being "subequal and tooth-like." The adults measure from 8 to 11 mm. in length and about 7 mm. in breadth. "The color varies from dusty brown to greenish brown in living specimens and turns reddish or blackish brown in alcohol." Eggs are deposited in small batches of from 10 to 80 at intervals of from three to fifteen days during a period of several months. The eggs are apparently readily deposited in captivity upon sand, as the writer has observed in other species of Ornithodorus. Hatching takes place in from 10 to 15 days and over, depending on temperature. Experimentally at least, the active larvæ attach themselves to a warm-blooded host, remaining attached for nearly a week, when they become disengaged and molt, the nymph now appearing. The nymphs feed at intervals, molting once or twice between each meal; there may be 6 to 9 molts and apparently young females molt even after sexual maturity has been reached, according to various observers, and indivduals may remain infective for over a year. Wellman has observed that this species attacks a wide range of animals besides man, notably pigs, dogs, goats and sheep; Nuttall found them to feed in his laboratory on rabbits, mice, rats, monkeys and fowls.

African Relapsing Fever is a disease of man occurring in Africa (Congo Free State, Angola and elsewhere), is caused by *Spirochœta duttoni* Novy and Knapp and is therefore a *Spirochœtosis.* The symptoms are described by Nuttall (1908, *loc. cit.*), viz.:

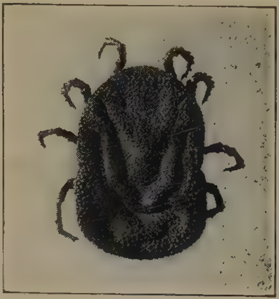

Fig. 201.—African relapsing fever tick, *Ornithodorus moubata.* × 3.

> "Headache, (especially at the back of the head), vomiting, abdominal pain and purging, with severe fever, a pulse of 90 to 120, dry hot skin, congested eyes and shortness of breath. After a period of fever lasting about two days, there is a fall of temperature, but a fresh attack soon follows. These relapses occur more frequently than in European relapsing fever, being usually 5 to 6 in number, but there may be more. The attacks leave the patient in a weak condition for a long time after recovery, which usually follows, but death occurs in about 6 per cent of the cases."

Dutton and Todd in 1905 and R. Koch in the same year showed that *Ornithodorus moubata* is a common and probably the usual carrier of this spirochæte disease. Leishman as well as Nuttall has shown that the tick is infective only through its excreta and not by its bite, that the clear coxal secretion is an anticoagulant and non-infective. The infection is hereditary in the tick as in Texas cattle fever, and what is more the spirochæte is transmitted to at least the third generation of ticks. The attack of fever takes place in the human in from 5 to 10 days after the tick has bitten.

Control.—Wellman's[1] recommendations, in part, to the government of Angola for the control of African relapsing fever are as follows:

> "(1) The tick in question should be regularly destroyed in crowded centers by disinfecting native houses, barracks and other permanent quarters, and by burning old camps, huts, etc.
>
> "(2) Soldiers, laborers on plantations, etc., should be made to keep their houses clean and to sleep in hammocks, or on beds well raised from the floor and away from the wall. Natives should never be allowed to sleep in or near the quarters of Europeans.

[1] Wellman, F. C., 1906. Human Trypanosomiasis and Spirochætosis in Portuguese South-west Africa with suggestions for preventing their spread in the colony. Journ. of Hygiene (Cambridge), Vol. VI, No. 3, pp. 237-245.

"(3) Soldiers, porters, servants, plantation laborers and other controllable bodies of natives should be compelled to observe regulations regarding regular bathing and washing of clothes."

The Spinose Ear Tick, *Otobius* (*Ornithodorus*) *megnini* Duges (Fig. 202), occurs commonly in California and other subtropical parts of the United States and Mexico. It receives its name from the fact that the nymph is covered with numerous spines and in all stages the tick attacks the ears of cattle, horses, mules and other domesticated animals and man. Rather large dark eggs are deposited by this species on the ground, where the seed ticks hatch. Under laboratory conditions at a temperature of about 21° C. the incubation period requires from 18 to 23 days. The newly emerged larvæ crawl up weeds and other vegetation like the larvæ of other ticks and gradually work their way to the deeper inner folds of the ears of the host where after molting a number of times, they reach maturity and drop to the ground during midsummer or early autumn. The writer has found that copulation takes place within a day or two after the final molt and that oviposition occurs in from 14 to 42 days after copulation with a maximum oviposition period of 155 days in the individuals observed during which time as many as 562 eggs were laid. The longevity of unfed larvæ at room temperature ranged from 19 to 63 days, with an average of 44 days.[1]

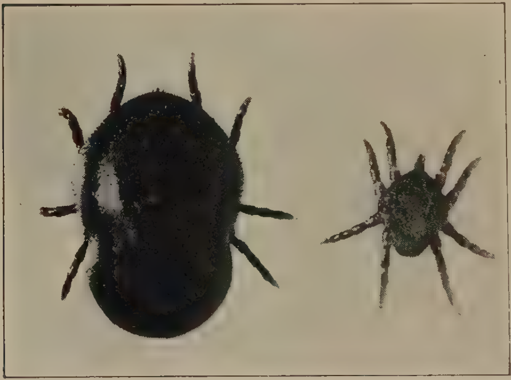

Fig. 202.—Spinose ear tick, *Otobius* (*Ornithodorus*) *megnini*. × 3.5.

Damage Done.—The writer has received many complaints from various cattle grazing districts in California relative to the "ear tick." Ears are occasionally sent in thoroughly infested with these pests in all stages. It is commonly asserted that this tick is responsible for much deafness in domesticated animals, and it is also believed to be responsible for illness and even death, particularly in calves.

Treatment.—Owing to the position occupied by the ticks on the host only local treatment is of any avail. A mixture of 2 parts of pine tar to 1 part of cottonseed oil injected with a warm metal syringe about ½ ounce in each ear (cattle and horses) is strongly recommended by Imes (U. S. Dept. of Agric. Bur. An. Ind. Farmers' Bull.

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[1] Herms, W. B., 1917. Contribution to the life history and habits of Orinthodorus megnini. Journ. Econ. Ent., Vol. 10, No. 4, pp. 407-411.

980). This mixture kills the ticks and affords protection against the invasion of others for about thirty days.

Other Species of Ornithodorus.—*Ornithodorus savignyi* (Audouin) occurs in Africa, India and Arabia and is believed to be a vector of African relapsing fever though not in a hereditary manner. *Ornithodorus talaje* (Guerin-Menev.) is known as the "talaje" and occurs in Mexico, Central America, portions of South America and probably California, attacking swine, cattle, man and other mammals. It produces a very painful bite like practically all other species of this genus and is believed to be a carrier of relapsing fever. *Ornithodorus venezuelensis* Brumpt believed to be the same as *O. turicata* Franco (not Duges according to Brumpt) transmits a relapsing fever of humans in Colombia and Venezuela[1] the causative organism of which has been named *Spirochæta* (*Treponema*) *venezuelense* by Brumpt. *Ornithodorus coriaceus* Koch is known as the "Pajaroello" and occurs in California and Mexico and is undoubtedly one of the most venomous species of ticks. (See Chapter XX.) The fact that two cases of relapsing fever have arisen from foci in California[2] is sufficient motive to study more carefully the species of *Ornithodorus* occurring in that vicinity and Mexico.

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[1] Brumpt, E. Les Spirochétoses. Nouveau Traité de Med. Fasc. IV, pp. 491-531.

[2] Briggs, LeR. H., 1922. Relapsing fever in California. Amer. Med. Assoc., Vol. 79 (Sept. 16, 1922), pp. 941-944.

CHAPTER XIX

MITES

Class Arachnida, Order Acarina

Characteristics.—In the mites, as in the ticks, the abdomen is broadly joined to the cephalothorax with little or no evidence of separation. All species are very minute, most of them being just about visible to the naked eye. The mites normally have four pairs of legs as have other Arachnids, but possess only three pairs (exceptionally less) as larvæ. The mouth parts are more or less tick-like and are fitted for piercing. One or more pairs of simple eyes are usually present. The respiratory system is in most species similar to that of the ticks, i.e., tracheal, while others absorb oxygen through the general body surface which in these is quite soft. Nearly all species deposit eggs; however, there are a few which are viviparous, among them Pediculoides. From the egg there emerges the hexapod larva, which usually soon molts and then presents its fourth pair of legs. The life history of many species is passed in less than six weeks, in some as short as eight days.

An infestation of mites is termed *acariasis*. Those species which burrow into the skin, producing channels and depositing therein their eggs, are said to produce *sarcoptic acariasis*, e.g., *Sarcoptes scabiei* var. *suis* of swine mange; while those species which deposit their eggs at the base of the hairs of the host or on the skin and pile up scabs, are said to produce *psoroptic acariasis*, e.g., *Psoroptes communis* var. *ovis* of sheep scab.

Although Banks[1] recognizes 29 families of mites only a few of these need be considered as affecting man or domesticated animals.

A. MANGE, OR ITCH MITES—SARCOPTIC ACARIASIS

Family Sarcoptidæ

Family Sarcoptidæ.—All members of the family Sarcoptidæ, commonly known as the itch mites, mange mites or scab mites, are very small (just about visible to the naked eye), whitish and somewhat hemispherical in form. Banks characterizes this family, viz.:

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[1] Banks, Nathan, 1915. The Acarina or mites. U. S. Dept. of Agric., Bur. of Ent. Report No. 108, 153 pp.

"The body is entire, and the surface transversely striated and provided with a few bristles, often short, stout and sharp-pointed. The legs are short and stout, arranged in two groups. The anterior legs are usually larger than the others. The tarsi commonly terminate in a stout claw. There is generally a long pedicellate sucker, sometimes with a jointed pedicel. The claw or sucker may be absent and in its place a long bristle. The legs often show a chitinous framework of rings, both transverse and oblique. On the front of the body is a prominent beak. The palpæ are small, three-jointed and appressed to the sides of the beak beneath. . . . There are frequently sexual differences; some males have the third pair of legs very large and long, while the fourth pair is very small. Sometimes there are plate-like lobes at the tip of the male abdomen, and the tarsi may terminate differently in the two sexes."

The family Sarcoptidæ includes a number of important genera, among them Sarcoptes, Psoroptes, Notoedres, Chorioptes, Otodectes and Cnemidocoptes, each producing a particular type of acariasis.

Mange or Itch Mites.—The mange or itch mites belong to the genus Sarcoptes, have very short legs, the posterior pair not extending beyond the margin of the nearly circular body (Fig. 203); suckers are present on the first and second pair of legs. The sarcoptic mites burrow in the skin, where they produce definite burrows in which the females deposit their eggs.

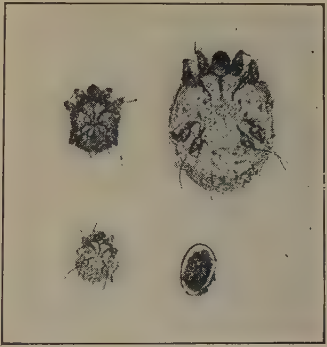

Fig. 203.—Showing life history and general characteristics of a typical sarcoptic (mange or itch) mite; egg (lower right); larva (lower left); male (upper left); female (upper right). *Sarcoptes scabiei* var. *suis*, the itch or mange mite of swine. × 57.

The species of Sarcoptes inhabiting the skin of mammals are ordinarily termed varieties of *Sarcoptes scabiei* L., the differences being very slight and many of them may interchange hosts, e.g., *Sarcoptes scabiei* var. *suis*, parasitic on swine and on man, and when on the latter is known as *S. scabiei* var. *hominis; Sarcoptes scabiei* var. *equi* of the horse is also parasitic on man. Given parasites, however, ordinarily exist only for a limited time on another host.

Human Itch.—The itch mite attacking humans is known as *Sarcoptes scabiei* var. *hominis* Raspail. It attacks by preference the thin skin between the fingers, the bend of the knee and elbow, the penis and other parts of the body, producing an almost intolerable itching. Infestation is ordinarily secured by direct contact, such as hand shaking, or exchange of clothing, towels, bedding, etc. Infection although subsiding temporarily due to cold or other causes may persist for years. The Norwegian itch caused by *Sarcoptes scabiei* var. *crustosæ* Fürst. is even more persistent.

Life History of Itch Mite.—The female mites deposit their rather large oval eggs in the tortuous tunnels which they have made in the epidermis. From 10 to 25 eggs are deposited by each individual. "The female, having deposited her complement of eggs, dies at the end of her burrow. As the skin of the host is always wearing off, and constantly being renewed from below, the eggs, when ready to hatch, will be close to the surface, so that the mites may readily escape. Above each burrow there is often a little pimple, containing a watery fluid" (Banks). The hexapod larvæ hatch in 3 or 4 days. In this stage the area of infection is most rapidly increased. Maturity is reached in 10 to 12 days, during which time there are said to be three molts. Gerlach, according to Braun,[1] has found that the progeny reproduce again in 15 days, and that each female produces about fifteen individuals, after which she dies. This rate of increase accounts for the rapid spread of itch on the individual host.

Treatment of Human Itch.—Inasmuch as the mites are protected in their tunnels in the epidermis, the skin must be thoroughly softened by massage with soap and hot water before a remedy is applied. Sulphur ointments give very good results, if applied repeatedly at intervals of three or four days. Tar, creolin, balsam of Peru, tincture of iodin, etc., are also used. Underclothing coming in contact with the parts affected should be boiled, steam sterilized or baked.

Swine Mange.—Mange of swine is caused by *Sarcoptes scabiei* var. *suis* Gerlach (Fig. 203). Mange attacks the swine commonly about the top of the neck, shoulders, ears, withers and along the back to the root of the tail. A microscopical examination of deeper tissue from beneath scabs will usually reveal the mites. Comparatively few cases of swine mange have come to the writer's attention in California, even in localities where swine raising is carried on extensively, hence it seems that the disease is not as widespread as might be expected.

Suckling pigs and young shoats suffer most. The affected animals scratch and rub vigorously, which may, however, be due to lice, but if the skin is cracked and thickly encrusted with heavy scabs, and the hair stands erect, an examination for scab mites should be made.

Infected animals should be isolated and immediately treated, the quarters should be disinfected with a 10 per cent creolin solution, 1 to 10 kerosene emulsion, 1 to 15 lime sulphur solution, or the like.

The life history and habits of the swine mange mite correspond in every respect with the itch mite of humans. This mite may infect man.

Treatment for Swine Mange.—In the treatment of swine mange, it is necessary to apply external remedies, in addition to sanitary precautions to prevent spread and reinfection of treated animals. Remedies are best applied in the form of solutions for the reason that all parts of the animal's body are thus easily reached in the dipping process. Hand dressing or scrubbing or the application of ointments may be practiced where dipping is not practical, but even so all parts of the animal should be thoroughly treated.

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[1] Braun, Max, 1908. The Animal Parasites of Man (English edition), William Wood & Co., New York. xix + 453 pp.

Mayo[1] of the Virginia Polytechnic Institute recommends a "lime and sulphur" dip most highly. He uses 8 pounds of fresh lime and 24 pounds of flowers of sulphur to 100 gallons of water, slaking the lime with sufficient water to form a thick paste, sifting in the sulphur and mixing with a hoe. This mixture is placed in a kettle with 25 to 30 gallons of water and boiled for one hour at least, two hours being better. Mayo suggests using the entire mass for swine, which must not, however, be done for sheep. The dip is used warm at a temperature of from 100° to 110° F. This temperature may be maintained by running a steam pipe along the bottom of the dipping vat.

Prepared "lime and sulphur" dips can be secured readily on the market, and are commonly used at the rate of one part of the solution to fifteen parts of water, however, care should be exercised to use the dip as directed, owing to variation in constituents. Coal tar dips are also used extensively and give good results if used properly.

Dipping vats may be made of wood or concrete and are usually set in the ground at a slight elevation to insure drainage away from the vat. A convenient size for a vat is "ten feet long on top, eight feet long on the bottom, one foot wide on the bottom and two feet wide at the top. The end where the hogs enter should be perpendicular and the other end inclined, with cleats, so that the hogs can emerge after passing through. The entrance should be by a slide. For pigs and small shoats that can be easily handled, a barrel serves the purpose well; the pigs can be caught, plunged in the dip and held there the required time. Some successful swine raisers build cement bathing places or wallows for swine and keep these filled with a watery solution of some dip or disinfecting solution. If swine have wallowing holes filled with water, some of the good dips should be put in these frequently." The time to treat young pigs, and this is important, is at weaning time. Dipping twice as for older animals is necessary, and by placing them in uninfected quarters they ought to remain clean.

Mangy swine should be hand dressed with a stiff brush before dipping in order to loosen up scabs, and then kept in the dip long enough to permit the solution to soak through the scabs, certainly not less than two minutes. All the animals must be dipped a second time in eight or ten days in order to destroy the mites which have hatched from the eggs which are not destroyed.

Mayo (1910, *loc. cit.*) recommends a disinfecting whitewash to be applied to pens, etc., viz., "Fresh lime, 25 pounds, flowers of sulphur,

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[1] Mayo, N. S., 1910. Some diseases of swine. Bull. No. 189, Virginia Poly. Inst. Agric. Exp. Sta., 19 pp.

15 pounds, mix the sulphur with a little water, to a paste, add 30 gallons of water and cook for an hour, then add water sufficient to make 50 gallons and apply with a spray pump, using a 'Bordeaux' nozzle."

Equine Mange.—Sarcoptic acariasis in horses, mules and asses is caused by *Sarcoptes scabiei* var. *equi* Gerlach. This species is also transmissible to man and is said to be the chief cause of the itch of cavalrymen and others handling horses extensively. Infestation of humans is, however, only temporary.

The most reliable diagnostic character is the discovery of the mite, which is accomplished as in swine mange. The usual symptoms[1] are first of all a strong tendency to rub some circumscribed part such as the head, root of the mane or tail, withers or back, due to an incessant itching. If a person scratches the affected parts, the animal moves its lips as though it were nibbling. The skin of these parts also shows an eruption of "fine conical papillæ." The hair stands erect and bristly, many having dropped out, but totally bare spots in which there are no isolated hairs apparently do not occur in mange, but do in ringworm according to Law. The affected parts are at first scurfy, then become covered with yellowish scabs, which latter exude matter due to the rubbing and inflammation, and finally there are formed scabs and crusts, often with deep crevices. During the first fourteen days the progress of the disease is usually slow, but by the sixth week the ravages of the disease become extensive and there is rapid progress.

The life history and habits of *Sarcoptes scabiei* var. *equi* correspond in every respect with other species already described.

Treatment for Equine Mange.—Before applying a local remedy for mange it is necessary to clip the entire animal so as to disclose all points of attack which might otherwise be hidden by hair. The clipped hair must not be blown by the wind and should be burned. The parts affected are next thoroughly lathered and left for a short while to soften, after which warm water is applied and the scabs rubbed off as far as possible with wisps of hay or straw and these also burned. The affected parts are now ready for a parasiticide, which should be applied by hand.

Many remedies may be had for mange, all of which have more or less virtue, but the writer has found that those containing sulphur have the greatest virtue. The ordinary "lime and sulphur" sheep dips applied locally and thoroughly, repeated three or four times at intervals of five days, ordinarily prove effective. Among other remedies Law (1905, *loc. cit.*) recommends creosote 5 parts, alcohol 5 parts, water 25 parts; to be rubbed in thoroughly two or three times at intervals of from three to five days. The application of a 2 per cent solution of "Chloronaphtholeum" applied as above proves very satisfactory, as does "Kreso" dip, one to forty. A liquid paste may be used, viz., first dissolve carbonate of soda in water and add brown soap and creolin (all in equal parts), dilute before using with 5 parts of water and apply with a hard brush for about half an hour and wash with clean water.

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[1] Law, James, 1909. Textbook of Veterinary Medicine, Vol. V, 621 pp., Ithaca, N. Y.

Stalls in which mangy horses have been kept must be disinfected with live steam or boiling water or mercuric chlorid 1 part to 500 of water. If the latter is used its very poisonous properties must be considered. Brushes, scrapers, rubbers, etc., must be boiled; harness must be rubbed thoroughly with a strong disinfectant, for example 2 per cent formaldehyd or "Chloronaphtholeum."

Bovine Mange.—Sarcoptic acariasis, or mange, in cattle is not common in this country, however, the psoroptic form (scabies) occurs quite abundantly.

Canine Mange.—Mange of dogs is caused primarily by *Sarcoptes scabiei* var. *canis* Gerlach closely resembling the swine variety. Mange in the dog appears first on the muzzle, around the eyes, on ears and breast and later spreads to the back, abdomen and elsewhere. Symptoms are much as in swine and horses. Canine mange is evidently transmissible to humans.

Treatment for Canine Mange.—Long-haired dogs must be clipped before applying a remedy. Law recommends the following treatment:

> "The whole skin may be covered with a solution of equal parts of green potash soap and alcohol and just enough carbolic acid to give it the odor. This is washed off next day and the surface is covered with the following: naphthalin, ½ oz., vaselin 2 oz., or alcohol 1 pint makes a most agreeable, if somewhat expensive dressing, which, though slow, is effective. Creolin 1 part, in alcohol 15 parts, is very efficient."

Tobacco, carbolic acid and other poisons which may be licked off by the dog should not be used, unless a tight muzzle is provided.

Mange of cats is caused by *Notœdres cati* var. *cati* Hering (= *Sarcoptes minor* var. *felis*), smaller and more circular than Sarcoptes but otherwise quite similar. Notœdric mange of cats begins at the tips of the ears and gradually spreads over the face and head. After clipping the hair in the region of the affected parts apply ointments only, such as sulphur two parts, potassium carbonate one part, and lard eight parts.

Other Mange Mites.—*Sarcoptes scabiei* var. *ovis* Megnin of sheep occurs on the face primarily and causes "black muzzle." *S. scabiei* var. *auckeniæ* Railliet occurs in llamas, and *S. scabiei* var. *capræ* Gerlach on goats.

Scaly Leg Mite on Poultry.—The legs of domestic fowls (chickens, turkeys, pheasants, etc.) are frequently covered with heavy scales and incrustations (Fig. 204). This condition is produced by a burrowing mite (Fig. 205), *Cnemidocoptes* (*Sarcoptes*) *mutans* Robin. The mites burrow and live in the skin, depositing their eggs in channels as do the mange mites. Scaly leg is easily transmitted from fowl to fowl, hence the infested birds should be isolated and treated.

Treatment of "Scaly Leg."—The legs must be soaked and manipulated with the hands in soap and warm water in order to soften the scabs. Then when dry, "apply a coating of balsam of Peru, or an ointment, containing 2 per cent of carbolic acid," or "a mixture of one part of oil of caraway with five parts of vaseline" (U. S. Dept. of Agric. Farmers' Bull. 530). The writer has repeatedly recommended dipping the legs of the fowl in a vessel containing one part kerosene and one part linseed oil; the oil must not touch the feathers on the legs otherwise the skin may suffer. This dipping process is best done while the birds are roosting, lifting each bird from the roost, dipping and then replacing it. The process should be repeated in not over a week.

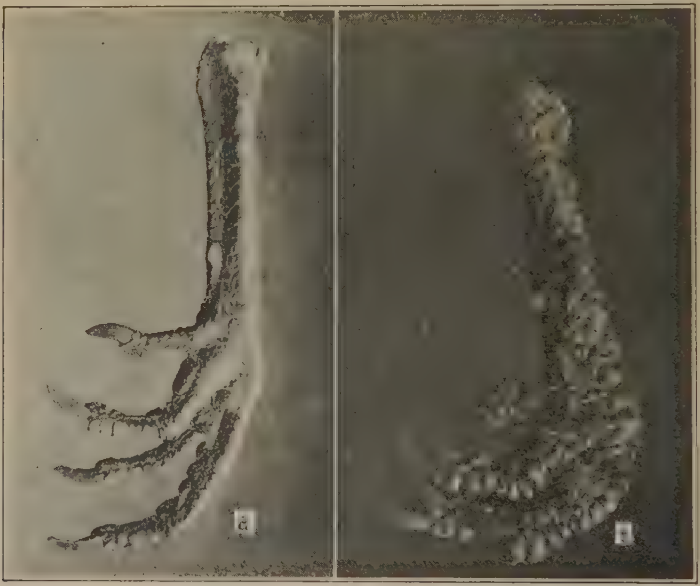

Fig. 204.—Showing (*a*) normal leg and claw of a fowl and (*b*) one affected with sarcoptic mites, *Cnemidocoptes mutans*, causing scaly leg.

Depluming Mite.—*Cnemidocoptes gallinæ* Railliet = *C. lævis* Railliet, known as the depluming mite, is closely related to the "scaly leg mite," but attacks the skin of the fowl near the base of the feathers. The mites themselves do not cause the bird to lose its plumage, but the intense itching caused by the mites impels the host to pluck its feathers in an attempt to reduce the itching. The depluming mite is not closely related to the *quill mite* (*Picobia bipectinatus* Heller), a rare species in California and Arizona which inhabits the quills of fowls and belongs to the family Cheyletidæ.

Dipping the birds in a 2 per cent solution of creolin, or in a 2 per cent solution of Zenoleum, or rubbing the skin with a sulphur ointment will, if the treatment is repeated, relieve the trouble considerably.

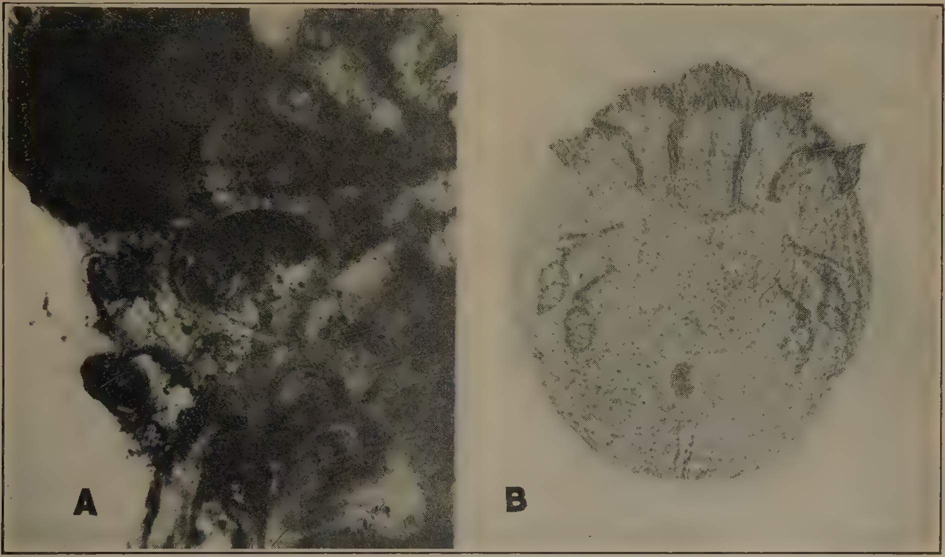

FIG. 205.—(*a*) Photograph of a portion of scale from a fowl affected with "scaly leg," showing mites (*Cnemidocoptes mutans*) *in situ;* (*b*) enlargement of an individual mite. × 170.

B. SCAB MITES—PSOROPTIC ACARIASIS

Family Sarcoptidæ

Characteristics of Psoroptic Mites.—The psoroptic or scab mites belong to the family *Sarcoptidæ* as do the itch and mange mites, hence partake of the family characteristics. However, in the psoroptic mites the legs are long and slender, all four pairs extending beyond the margin of the body which is elongate (Fig. 206). The "pedicel of the suckers is jointed" and the "mandibles styliform, serrate near tip" and suited for piercing. The psoroptic mites do not burrow, as do the sarcoptic mites, but live at the base of the hairs of the host, piercing the skin, causing an exudate which partially hardens, forming scabs which pile up as a crust of loose humid matter. This condition is known as *scabies* or *scab*. Among the piled up scabs are deposited the eggs. Owing to the loose condition of the scabs and the hardihood of the mites, this form of acariasis becomes quickly and easily distributed from animal to animal by contact and by rubbing against fences, trees, and the like.

The commonest scab mites belong to the genus Psoroptes of which *Psoroptes communis* var. *ovis* Hering (Fig. 207) of the sheep is best known. Other varieties of this species infest cattle and horses mainly.

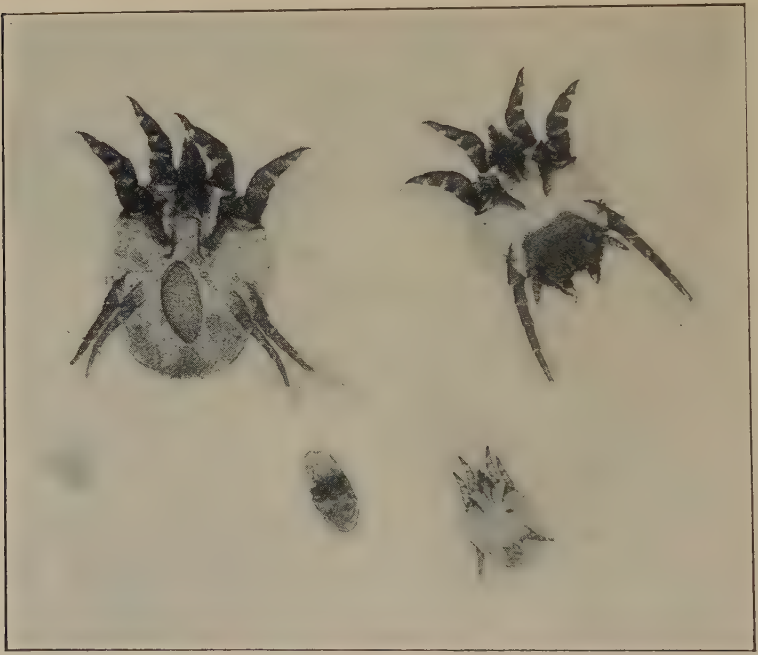

FIG. 206.—Showing life history and general characteristics of a typical psoroptic or scab mite. Egg (lower left); larva (lower right); male (upper right); female (upper left). *Psoroptes communis* var. *equi* of the horse. × 85.

Ovine Scabies (Sheep Scab) *Psoroptes communis* var. *ovis* Hering (Fig. 207) is the causative organism of scabies in sheep. This is by far the most important species of scab mite. However, with the widespread use of dips, and rigid quarantine regulations, scabies in sheep is gradually being controlled.

The sheep scab mite is easily visible to the naked eye. The adult female measures about "one fortieth" of an inch in length by "one-sixtieth" of an inch in breadth, and the male "one-fiftieth" by "one-eightieth" of an inch. As in all psoroptic species the mites are found on the surface of the body among the scabs at the base of the hairs.

The parts of the body most thickly covered with wool are chiefly affected.

Symptoms of Sheep Scab.—Scabies is first indicated by a slight "tagging" of the wool, the coat becomes rough, ragged and matted at the points affected (Fig. 208). Tags of wool are torn away by the sheep or are left attached to rubbing posts and other objects against which the animal rubs. The sheep scratches vigorously and shows signs of intense itching.

"The skin of the affected part is covered with yellowish papules of varying size, and a marked accumulation of scurf among the roots of the wool. Later the affected skin swells uniformly, and the increasing exudation concretes into a massive scab enveloping the roots of the wool, so that as it increases layer by layer on its deeper surface, it lifts the fibres out of their follicles, detaching the wool and leaving extensive bare scabby patches. The denuded surface shows all the variation of lesions shown in other mangy animals. Papules, vesicles, pustules, scabs, cracks, excoriations, and even sloughs may appear at different points. Sometimes in clipped sheep the exudate forms a uniform, smooth, parchment-like crust covering the whole exposed area. Around these bare patches the wool is encrusted at its roots, or shows a dark, dirty, scurfy layer composed of epidermic cells, yolk, dried exudate and the exuviæ of the acarus. Beneath this the parasite is found in myriads. The bare spots may show comparatively few" (Law).

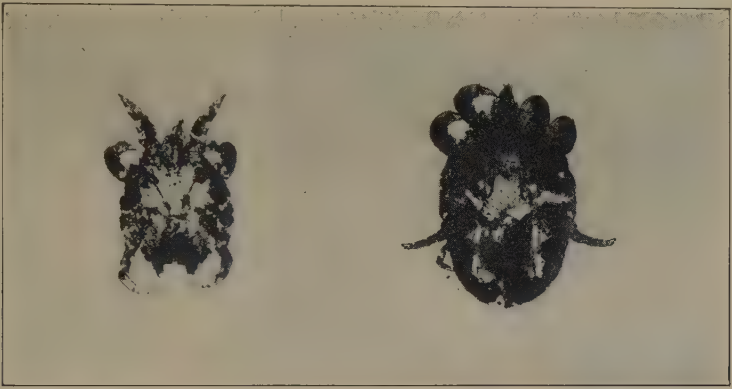

Fig. 207.—Sheep scab mite, *Psoroptes communis* var. *ovis;* male (left); female (right). × 75.

Life History of the Scab Mite.—The female scab mite deposits an average of about 15 (maximum 30) eggs, one at a time, and the period of oviposition often lasts several days, when the female evidently dies. The eggs are either attached to the wool near the skin or deposited directly upon the latter. The hexapod larvæ hatch in from 3 to 7 days, the first molt taking place in 3 or 4 days when the fourth pair of legs appears; a second and third molt takes place within the next 4 or 5 days. Sexual maturity is evidently reached about the time of the second molt. Although there is considerable variation in the length of time elapsing from egg to egg, 12 to 14 days is ordinarily accepted as an average.

Treatment for Sheep Scab.—Internal remedies, such as sulphur, have been found to be unsuccessful by the U. S. Department of Agriculture. However, sulphur applied externally in the form of "lime and sulphur" dip has been used for many years as a successful remedy. Several kinds of dips with variations are commonly used against sheep scab, among them, lime and sulphur, tobacco and sulphur, tobacco, cresol, coal tar products, Chloronaphtholeum, Kreso, etc. If proprietary dips are used, extreme care must be exercised in following the directions. The dip should have the approval of the U. S. Department of Agriculture. All dips must be repeated in seven or eight days and not later than ten days in order to destroy the mites newly hatched from eggs, since very few dips, except perhaps creosote dips, are injurious to the eggs.

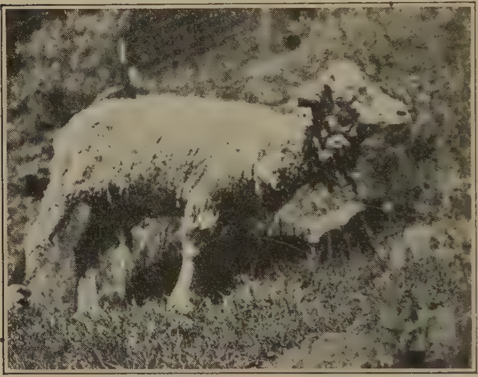

Fig. 208.—An advanced case of sheep scabies.

Lime and Sulphur Dips.—Experience in many sheep-raising districts has proved that lime and sulphur dips are most efficient in the control of scab, if properly used. Damage to the wool, if dipping is done shortly after shearing, is very slight indeed. If there is any doubt, or injury has been produced in the use of lime and sulphur, other dips are available, notably nicotin.

Among the varieties of lime and sulphur dips mentioned by the U. S. Bureau of Animal Industry[1] are the following:

1. For fresh scab (U. S. B. A. I. formula):

Flowers of sulphur	24	lbs.
Unslaked lime	8	lbs.
Water	100	gals.

2. For very hard scab (Fort Collins formula):

Flowers of sulphur	33	lbs.
Unslaked lime	11	lbs.
Water	100	gals.

3. For unusually severe cases (Nevada formula):

Flowers of sulphur	16⅔	lbs.
Lime	33⅓	lbs.
Water	100	gals.

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[1] Salmon, D. E., and Stiles, Ch. Wardell, 1903. Scab in Sheep. U. S. Dept. Agric., Farmers' Bull. No. 159, 45 pp.

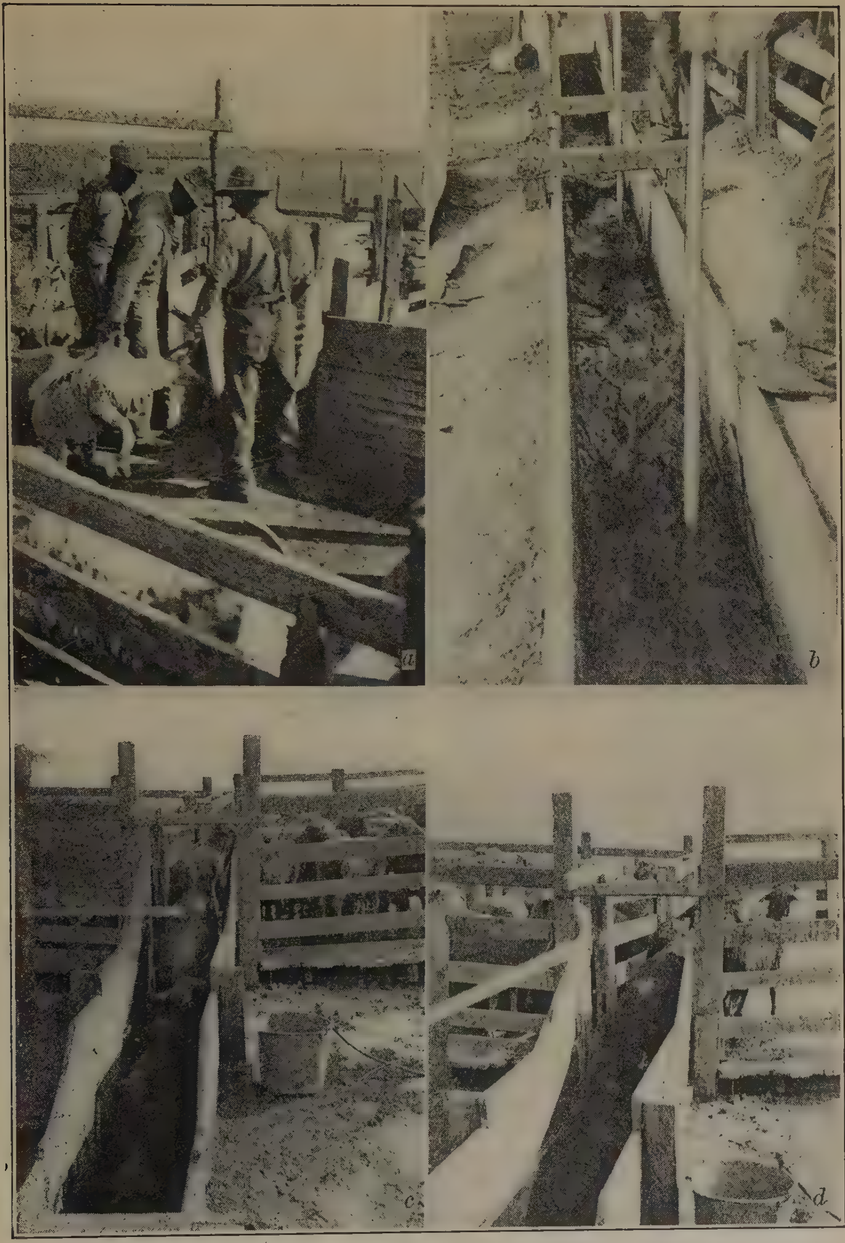

FIG. 209.—Dipping sheep. (*a*) plunging the sheep into the vat; (*b*) sheep swimming through the vat; (*c*) sheep emerging from the vat; (*d*) entering the pens after emerging from the vat. (Photo by G. P. Gray.)

According to the U. S. Bureau of Animal Industry "thirty-three pounds of lime to one hundred gallons of water is the largest proportion admissible under any circumstance."

How to Prepare Lime and Sulphur Dip.—Much time may be saved by purchasing the lime and sulphur already prepared and using it as directed, but the mixture may be prepared as follows, as directed by the United States Department of Agriculture:

"*A.* Take 8 to 11 pounds of unslaked lime, place it in a mortar box or a kettle or pail of some kind, and add enough water to slake the lime and form a 'lime paste' or 'lime putty.'

"Many persons prefer to slake the lime to a powder, which is to be sifted and mixed with sifted sulphur. One pint of water will slake three pounds of lime, if the slaking is performed slowly and carefully. As a rule, however, it is necessary to use more water. This method takes more time and requires more work than the one given above, and does not give any better results. If the boiled solution is allowed to settle, the ooze will be equally as safe.

"*B.* Sift into this lime paste three times as many pounds of flowers of sulphur as used of lime, and stir the mixture well.

"Be sure to weigh both the lime and the sulphur. Do not trust to measuring them in a bucket or to guessing at the weight.

"*C.* Place the sulphur lime paste in a kettle or boiler with about 25 or 30 gallons of boiling water, and boil the mixture for two hours at least, stirring the liquid and sediment. The boiling should be continued until the sulphur disappears, or almost disappears, from the surface; the solution is then of a chocolate or liver color. The longer the solution boils the more the sulphur is dissolved, and the less caustic the ooze becomes. Most writers advise boiling from thirty to forty minutes, but the Bureau obtains a much better ooze by boiling from two to three hours, adding water when necessary.

"*D.* Pour the mixture and sediment into a tub or barrel placed near the dipping vat and provided with a bunghole about four inches from the bottom and allow ample time (two to three hours, or more if necessary) to settle.

"The use of some sort of settling tank provided with a bunghole is an absolute necessity, unless the boiler is so arranged that it may be used both for boiling and settling. An ordinary kerosene oil barrel will answer very well as a small settling tank. To insert a spigot about three to four inches from the bottom is an easy matter. Draining off the liquid through a spigot has the great advantage over dipping it out, in that less commotion occurs in the liquid, which therefore remains freer from sediment.

"*E.* When fully settled, draw off the clear liquid into the dipping vat and add enough warm water to make 100 gallons. The sediment in the barrel may then be mixed with water and used as a disinfectant, *but under no circumstances should it be used for dipping purposes.*"

The Dipping Vat.—Dipping vats may be constructed either of wood or of concrete, should be about nine inches wide at the bottom, two feet six inches at the top, about 5 feet deep, and 35 to 40 feet in length. The entrance end is built steep while the exit end has a gradual slant provided with cleats.

How to Proceed.—The sheared sheep are driven into the receiving pen, the dip having been prepared in the meantime and warmed to 102° to 105° F. One after another the sheep are forced into the dip, in which they must be kept two minutes and the head drenched at least once while traveling toward the exit end of the vat (see Fig. 209). From the vat the sheep emerge in dripping pens.

Tobacco Dips.—Tobacco (nicotin) dips are now used very extensively with excellent results. Tobacco dips are used either with or without sulphur. Owing to variation in nicotin content, homemade dips or proprietary tobacco dips are not safe unless the percentage is ascertained. When diluted ready for use the *nicotin content must be* .07 *of one per cent,*—a requirement of the Bureau of Animal Industry.

After a very careful and rigid experiment conducted by the Kentucky Agricultural Experiment Station [1] in coöperation with the Bureau of Animal Industry with reference to the addition of sulphur, the following conclusions were reached:

> "With the conditions under which this experiment was carried on, as given in this bulletin, the addition of flowers of sulphur in the prescribed dilutions of nicotin did not, as far as could be discerned, enhance the value of these dips in curing sheep of the disease of scabies.
>
> "After the conclusion of the above experiment, dippings were conducted by the Bureau of Animal Industry on the western ranges under field conditions. The results were confirmatory to the conclusions drawn from the above experiments and a ruling was made by the Bureau, taking effect May 1, 1911, withdrawing the requirement that sulphur be added to tobacco dips. The ruling requires that seven-hundredths of one per cent of nicotin be used at each dipping."

The second dipping in the above experiment was given in ten days and the temperature of the water was 105° F.

A tobacco extract containing 2.9 per cent nicotin must (according to the above bulletin) be diluted with 56.85 gallons of water to produce .07 per cent nicotin dip, or 80.14 gallons of water for a .05 per cent nicotin dip. Nicotin sulphate (about 40 per cent nicotin) must be diluted with 86.17 gallons of water for .07 per cent nicotin or 120.70 gallons for a .05 per cent solution.

If sulphur is used with tobacco, 16 pounds of flowers of sulphur are required per 100 gallons of water. The sulphur is made into a thin paste with water before adding it to the dip.

Other Dips Used for Sheep Scab.—Great care should be exercised in selecting proprietary sheep dips; many are unreliable and result in waste of money, time and energy. The carbolic acid dips vary considerably in their cresol content even in packages sold under the same label. At all events use the dip exactly as recommended. Among the more widely used dips other than those mentioned above are Kreso, used 1 to 72, Zenoleum, 1 to 50, and Chloronaphtholeum, 1 to 50. The rating of the U. S. Bureau of Animal Industry should govern the choice of the remedy. The requirements are that when diluted for use they shall contain "one per cent by weight of coal-tar oils and cresylic acid. In no case should the diluted dip contain more than four-tenths of one per cent nor less than one-tenth of one per cent of cresylic acid." These preparations cannot be used in very hard water except by a preliminary water softening. Hard water may be softened by dissolving lye at the rate of 12 ounces of high grade concentrated lye to 100 gallons of water, then add the dip. If the emulsion still breaks or forms in globules after treating with lye it will probably be necessary to use lime-sulphur solution or an arsenical dip.

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[1] Good, Edwin S., and Bryant, Thomson R., 1911. The dipping of sheep for scabies in tobacco dips with and without the addition of flowers of sulphur. Kentucky Agric. Exp. Sta. Bull. No. 157, pp. 183-193.

Bovine Scabies.—Scabies in cattle is caused by *Psoroptes communis* var. *bovis* Hering and is comparatively common. The disease usually appears at the root of the tail, thighs, neck and withers and spreads rapidly to other parts of the body. According to Imes[1] heavy losses may result from this disease.

Treatment for scabies in cattle is most successfully undertaken with tobacco sulphur dips or lime and sulphur dips. The former is used as in sheep scab, while in the latter twelve pounds of unslaked lime and 24 pounds of flowers of sulphur to 100 gallons of water are used.

The following general directions are given by the South Dakota Agricultural Experiment Station:[2]

> "1. The temperature of the dipping vat should be constantly maintained at from 103° F. to 105° F.
>
> "2. Animals badly affected are preferably to be hand dressed by scrubbing the scabby areas with a stronger solution of the dip. When lime and sulphur is used this has the effect of softening the firm scab, allowing the dip to penetrate.
>
> "3. Each animal should be held in the vat for two minutes, and completely immersed twice.
>
> "4. All animals that have been in contact with the diseased ones should be regarded as infected and dipped.
>
> "5. The dipping should be repeated in from ten to fourteen days to destroy the parasites that may have hatched out subsequently to the first dipping."

C. AURICULAR MITES—OTOACARIASIS

Family Sarcoptidæ

Auricular Mites.—A comparatively common affection of domesticated rabbits, also cats and dogs, is known as *otoacariasis* or parasitic *otitis* and is traceable to *Symbiotes auricularum* Railliet or *Otodectes*

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[1] Imes, Marion, 1918. Cattle scab and methods of control and eradication. U. S. Dept. of Agric., Farmers' Bull. 1017. 29 pp.

[2] Moore, E. L., 1911. Scabies (Mange) in Cattle. Agric. Exp. Sta. South Dakota State College of Agr. and Mech. Arts, Bull. 131, pp. 203-216.

cygnotis Gedoelst, resembling Psoroptes very closely. The mites literally swarm in the ears of their host, causing much discomfort, tenderness of the ears, auricular catarrh, loss of appetite, wasting, torticollis, "fits," etc.

Cleansing the ears first with soapsuds and warm water, and then applying a sulphur ointment or a 10 per cent solution of tincture of iodin in glycerin, or a 1 per cent solution of carbolic acid in linseed oil is recommended. Banks recommends injecting olive oil containing one-tenth part of naphthol. The hutches or kennels must be thoroughly disinfected with a strong lime-and-sulphur solution or carbolic acid to prevent further contagion.

D. Foot Scab—Chorioptic Acariasis

Family Sarcoptidæ

Chorioptic acariasis.—Mites belonging to the genus *Chorioptes* produce a scab similar to sheep scab but restricted to certain parts of the body such as the feet and neck. *Chorioptes symbiotes* Verheyen = *C. equi* Gerlach attacks the lower parts of the legs of horses particularly those with long hairs on the fetlocks. The same species is said to occur at the base of the tail of cattle. A mixture of 1 part carbolic acid to 15 to 20 parts of linseed oil, or equal parts of kerosene and linseed oil are recommended as treatment. Several applications are needed to effect a cure.

E. Pulmonary Acariasis

Family Parasitidæ

Pulmonary acariasis of monkeys is said to occur and is traceable to mites of the genus *Pneumonyssus* which live in the lungs of the host. *Halarachne attenuata* Banks occurs in the air passages of Alaska seals and *Sternostomum rhinolethrum* Trouessart is said to produce catarrhal inflammation in fowls.

F. Follicle Mites—Follicular Mange

Family Demodicidæ

Characteristics of Follicle Mites.—The Demodicidæ include very minute (.3-.4 mm.) mites with elongated transversely striated abdomen and possessing four pairs of "stubby" three-jointed legs (Fig. 210).

The follicle mite (*Demodex folliculorum* Simon) inhabits the hair follicles and sebaceous glands of man and other mammals "causing inflammation of the gland (comedones); their agglomeration in the meibomian glands (in man) sets up inflammation of the margins of the eyelids" (Braun). While the follicle mites may, under certain conditions, produce acne-like conditions, it is hardly probable that many cases of "black-head" if any, may be traceable to these mites. They are nevertheless very common,—said to occur in 50 per cent of mankind in all parts of the world.

In most animals the follicle mites are found in the region of the muzzle and the affection is known as *follicular mange,* manifested by a reddish raw appearance. According to Banks *Demodex bovis* Stiles has been recorded from hides of American cattle in which swellings about the size of a pea were formed on the skin. In these swellings great numbers of the mites occurred. The value of the hides is said to be lessened to a considerable degree. *Demodex phylloides* Caskor inhabits the skin of swine both in the United States and Canada, producing white tubercles.

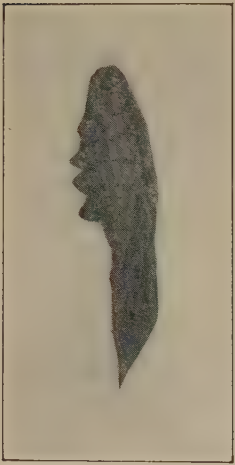

Fig. 210.—A follicle mite, *Demodex folliculorum.* × 110.

Owing to the fact that the follicle mites occur so deeply in the skin, treatment is made very difficult. Penetrating materials are necessary, for example, benzine, 1 part, and olive oil, 4 parts, or applications of tincture of iodin. Frequent applications must be made until a cure has been effected which is doubtful. The following treatment for follicular mange in dogs is said to be of value,—wash the dog with soap and water, then cleanse thoroughly and empty the pustules, after which soak the parts affected (or dip the animal) for five minutes in 5 per cent formalin or 2 per cent formaldehyd, following this with an application of sulphur ointment,—repeat the treatment every three or four days until four or five treatments are given. The use of ichthyol prepared with lard or lanolin in the proportions of one to seven is suggested by Underhill.[1] The chances for the cure of follicular mange are slight and valuable dogs should be placed under the care of a skilled veterinarian where facilities are available for the production and administration of autovaccines.

G. HARVEST MITES OR CHIGGERS

Family Trombidiidæ

Characteristics.—Members of the family Trombidiidæ are commonly known as "harvest mites," "jiggers," or "red bugs." In Mexico they are known as "Tlalsahuate." The tsutsugamushi, akamushi or kedani mite of Japan also belongs to this group. According to Banks they "are recognized by the body being divided into two portions, the anterior (cephalothorax) bearing the two anterior pairs of legs, the palpi mouth parts and eyes; the posterior (abdomen) is much larger and bears the two posterior pairs of legs. The mandibles are chelate, at least there is a distinct jaw or curved spine-like process. They are always red in color, some, however, being much darker than others. The body is covered with bristles or feathered hairs according to the species. The palpi are five-jointed, quite prominent, often swollen in the middle, the penultimate joint ending in one or two claws, the last joint (often clavate) appearing as an appendage or 'thumb' to the preceding joint. The legs are seven-jointed; the tarsi terminate in two small claws. The legs are clothed in the same manner as the body. There are two eyes upon each side of the cephalothorax, quite frequently borne on a distinct pedicel."

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[1] Underhill, B. M., 1920. Parasites and Parasitosis of the Domestic Animals. Macmillan Co., New York. 379 pp.

The most important genus affecting man is Trombidium, of which the larval form is known as Leptus (Fig. 211), e.g., *Leptus irritans* Riley, and *Leptus akamushi* Brumpt. Among the species of Trombidium are *T. holosericeum* Linn., *T. inopinatum* Oude.

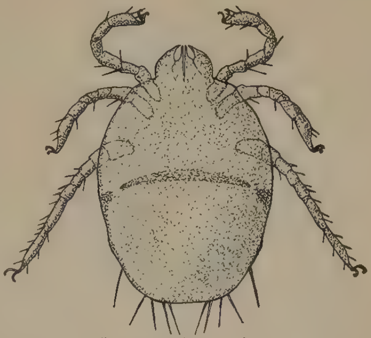

FIG. 211.—Chigger mite or harvest mite;—larva (Leptus) of Trombidium. × 150.

Habits and Life History. — The adult mites are largely ground and crevice inhabiting, sucking the juices of many species of insects such as plant lice, grasshoppers, etc. The eggs are deposited on the ground or in crevices during the spring. The newly hatched larvæ are hexapod and ground inhabiting where they appear to prey parasitically on insects and small mammals such as mice. In this connection it is of interest to note that Ewing[1] came to the conclusion after a careful and prolonged study that the determination of the natural hosts of our American chiggers has not been made and that further investigation along this line is needed.

It is quite generally stated that chiggers burrow into the skin of their human hosts and there die, but Ewing arrived at a different conclusion after a series of observations, viz.:

> "To find out whether chiggers penetrate the skin or not, and also to observe their injury, resort was made to experimentation. On July 15,

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[1] Ewing, H. E., 1921. Studies on the biology and control of chiggers. U. S. Dept. of Agric. Bull. 986, 19 pp.

1919, the writer exposed the left calf and ankle to chigger attack. Daily observations were made on these chiggers, using low and high power lenses, for the next eight days. It was observed on the first day that the mites attached only by their mouth parts and in no way burrowed into the skin. Observations on the second day showed no change; in fact, after once attaching to the skin by their mouth parts the larvæ became quiescent and did not change their position until they dropped off. . . .

"Of the 26 numbered individuals that were observed and studied daily, 21 were attached to the smooth surface of the skin, while 5 were attached at the bases of hairs, each having the capitulum thrust into the mouth of the hair follicle. Not a single one had penetrated a pore or hair follicle.

"The species occurring in the northeastern part of the United States shows a tendency to attach at the mouth of hair follicles. It may be that the larvæ actually try to enter. They are prevented, however, from doing so under normal conditions of the skin by the small diameter of the follicles themselves. For this same reason it would be impossible for chiggers to enter the pores of the skin, unless the latter were greatly dilated as a result of some skin trouble. In diameter the pores of the skin range from 20 to 50 μ, according to Piersol. The width of an unengorged larva from either the western or eastern part of this country is approximately 150 μ. Thus it is seen that unless the pores were unusually dilated the mites could not enter if they would."

Injury Due to Chiggers.—Inflammation due to the chiggers or red bugs are usually acquired during late summer or autumn (whence the name autumn mite or harvest mite) by walking through infested pastureland or similar situations. The writer has suffered repeated attacks while on biological trips in certain parts of Ohio. Picnic parties often pick out some lovely green spot on which to sit or recline while eating their lunches and are the particular objects of chigger attack, affording a much greater surface for invasion and consequently the results are usually more severe than in cases of more restricted attack such as the ankles only.

The chiggers at first simply swarm over the parts invaded, scurrying about in lively fashion but in an hour or two have attached themselves to the skin and the burning sensation begins within a few hours, increasing in intensity usually during the following thirty-six hours. Red blotches first appear and water blisters of larger or smaller size usually form in a day or two after the itching begins.

If the invasion is slight, no general disturbance is suffered but extreme infestations produce a slight fever and a peculiar nervous effect, sleep being almost impossible.

Tsutsugamushi disease also known as Kedani disease or Japanese Flood fever is an acute exanthematous infectious disease, which occurs in the northern coast districts of Japan and in Formosa. It resembles Rocky Mountain Spotted Fever very closely and demands a mortality of between 20 and 50 per cent. The causative organism has not as yet been discovered, but Nagayo, Miyagawa, Mitamura and Imamura[1] state that certain piroplasma-like forms discovered by them and occurring in the spleen, in the red corpuscles, and which may belong to the Sporozoa may be the cause. They also propose changing the name of the acarine carrier from *Trombidium akamushi* Brumpt to *Leptotrombidium akamushi.* The larvæ feed on warm-blooded animals including man and are found throughout the year; they are orange red in color and "can be distinguished from a grain of sand only by its movement." Evidently a field mouse (*Microtus montebelli*) is a common host of the akamushi mite and also acts as a reservoir for the disease.

Treatment for Harvest Mites.—The extreme irritation occasioned by these mites may be relieved considerably by bathing, using soap freely, followed by sponging with a weak solution of carbolic acid (an ounce to a quart of water), weak ammonia, soda solution, or alcohol, or anointing the affected spots with an ointment or salve containing sulphur. Dusting the hosiery and underwear with sulphur is recommended by Ewing as an admirable protection against chiggers.

H. The Poultry Mite

Family Dermanyssidœ

Dermanyssus gallinœ Redi, the poultry mite, is the the most important member of the Family Dermanyssidæ. While this species is widely distributed in the United States another slightly larger species, *S. hirundinis* (Hermann) also troublesome to poultry is more localized in its distribution.

Habits and Life History.—In size the mites vary from .6 to .7 mm. in length, are somewhat pear-shaped and are light gray when unengorged and from light to a dark red when engorged (Fig. 212).

During the daytime the mites remain hidden in the crevices of the henhouse, under the roosts, under boards, etc. In these hiding places the eggs are deposited. At night the little pests swarm out from their hiding places and attack the fowls upon the roosts. Their attack on the fowls is, however, not restricted altogether to the night, but swarms of them may be found on sitting hens and laying hens during the day while nesting in darker situations.

Eggs are deposited in all sorts of crevices. The six-legged larvæ hatch in 2 to 6 days, and after molting in about 24 hours without feeding take their first meal of blood as a first-stage nymph. After two more molts if food is available the adult stage is reached. Under favorable conditions only 10 days are necessary for the mite to pass through all its developmental stages. Wood,[1] who has studied this mite most carefully, states that under natural conditions in August this time would be reduced to at least 8½ days. Full growth is reached in from 3 to 6 weeks, depending on temperature. Some authors give the time for development at from 10 days to 2 weeks. There are three or four molts before sexual maturity is reached.

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[1] Nagayo, M., Miyagawa, Y., Mitamura, T., and Imamura, A., 1917. On the nymph and prosopon of the Tsutsugamushi, *Leptotrombidium akamushi, N.* sp. (*Trombidium akamushi* Brumpt) carrier of the Tsutsugamushi disease. Journ. Exp. Med., Vol. 25, No. 2, pp. 255-272 (4 plates).

Damage Done.—The poultry mite is one of the worst enemies of the poultry raiser in the Southern states and in California, and is evidently a serious pest in many other parts of the world. The damage which this mite produces is very considerable and may be summarized as follows: egg production is greatly reduced or entirely prevented as shown by Repp;[2] sitting hens are often caused to leave their nests or perish; newly hatched chicks perish in great numbers in the presence of these mites; chickens lose flesh, are unthrifty, and are unprofitable for marketing; loss of blood and reduced vitality cause birds to be easily susceptible to disease.

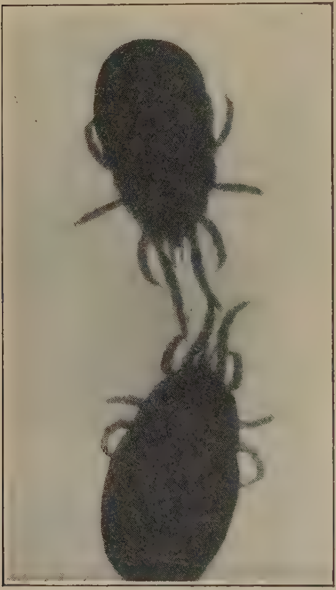

FIG. 212.—The poultry mite, *Dermanyssus gallinæ.* × 45.

Control of the Poultry Mite.—Inasmuch as the mites are seldom found on the bodies of the birds during the day, except in the first feeding period when they sometimes remain attached for a night and a day, or in dark nest boxes, control measures are directed most advantageously against the hiding places. A thorough clean-up of the premises to which the birds have access, together with the elimination of every useless article therein, such as boxes, coops, boards, etc., is the first step. Old nesting material should be burned and if the infestation is severe, roosts and nests should be dismantled to be replaced by construction that will facilitate future clean-ups. Methods must now be directed against the cracks and crevices of the floors, walls, and even the roof of the poultry house. In heavy infestations the mites sometimes migrate to the outside of the house when the inside is sprayed. They should be looked for along the cracks on the outside and, if present there, a spraying of the outside will be decidedly worth while. The most efficient manner of accomplishing this end is by the use of liquid insecticides applied preferably by "bucket" or "knapsack" spray pumps. A coarse spray is most effective and should be applied to each area from several different angles to insure penetration into all hiding places. Many of the existing sprays are efficient. Any of the dips used on domesticated animals made up in a slightly stronger solution than directed for the dipping of domesticated animals will give fairly satisfactory results. The most satisfactory of all applications, however, are the wood preservers similar to *"Carbolineum"* that have the coal-tar product anthracene oil as a base. These have the advantage of being effective over a long period and of soaking into the wood rapidly without leaving a greasy residue to soil the feet, feathers and eggs of the birds. They should be diluted about one-half with kerosene to facilitate spraying. One careful, thorough treatment generally proves sufficient with this type of spray. *Crude oil* diluted sufficiently with kerosene to make it easily sprayed is efficient in killing the mites and is sufficiently durable but leaves the roosts, floors, etc., in an oily condition so that the flock must be excluded from the treated premises for some time in order to avoid soiling of feathers and eggs. *Whitewash* containing 3 to 5 per cent of crude carbolic acid kills large numbers of mites but is not nearly as effective as anthracene oil or crude oil.

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[1] Wood, H. P., 1917. The chicken mite; its life history and habits. U. S. Dept. of Agric. Bull. No. 553, 14 pp.

[2] Repp, John J., 1903. The chicken mite. Iowa State College Exp. Sta. Bull. No. 69, pp. 287-294.

Prevention.—The common chicken mite is introduced into clean flocks in many cases in contaminated shipping coops. In some cases the introduction may be accomplished by a few young mites that are engorging for the first time on the introduced fowls. To overcome this possibility, newly acquired birds should be kept in special coops for two or three days before being placed in clean houses. These coops should then be destroyed or disinfected with boiling water or with one of the sprays suggested above. Shipping coops from other poultry plants should not be left in or near clean houses, nor should second-hand equipment be introduced unless the proper precautions of disinfection are taken. Mites will live for from three to five months without food, a fact which should be considered when vacant buildings are to be occupied by clean flocks. In cases where the control of the mite is impossible owing to the character of the quarters or lack of them, some relief is afforded by wrapping the ends and other points of contact of the roosts which have been painted thoroughly with crude oil, with rags soaked in the same substance to prevent the mites from gaining access to the fowls after they have roosted. To make this procedure effective crowding should be discouraged and the back roosts should not be near enough to the wall to permit the movement of the mites to the plumage of the birds.

Mites on canary birds require both the treatment of the birds and the cages, particularly the latter. The bird should be temporarily removed from the cage and dusted with fresh pyrethrum powder or buhac, while the cage and contents are being dipped in boiling water or baked in an oven.

Tropical Fowl Mites (*Liponyssus bursa* Berlese) have recently been reported for the United States by Wood[1] and if the species becomes established may be a menace to the poultryman. It is a common species on fowls in China, India, South America and Africa. Unlike *Dermanyssus gallinæ* above described, the Tropical Fowl Mite remains on its host much of the time where it commonly lays masses of eggs in the fluff of the feathers. It is much smaller in size than *Dermanyssus gallinæ* as stated by Wood, who recommends dipping the fowls in a mixture of 2 ounces of sulphur, 1 ounce of soap and 1 gallon of water and treating the nests, floors, roosts, etc., with carbolineum. The English sparrow serves as a favorable host for this species of mite, and would no doubt be an effective agent in dissemination.

I. LOUSE-LIKE MITES

Family Tarsonemidæ

Characteristics of Tarsonemidæ.—This is a small family of soft-bodied mites having in the female a characteristic "prominent clavate organ of uncertain use" between the first and second pairs of legs (Fig. 213). The third and fourth pairs of legs are separated from the first and second pairs by a long interspace. There is present a considerable sexual dimorphism in the several species. The piercing, sucking mouth parts are provided with slender needle-like stylets. Many of the species are predaceous or parasitic, while others suck the juices of certain plants.

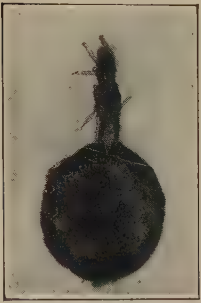

FIG. 213.—A louse-like mite, *Pediculoides ventricosus.* × 32.

Pediculoides ventricosus Newport is a widely distributed predaceous mite which attacks the larvæ of a number of species of insects such as the Angoumois grain moth (*Sitotroga cerealella* Oliv.), the wheat joint-worm (*Isosoma tritici* Fitch), the peach twig borer (*Anarsia lineatella* Zell.), the cotton-boll weevil (*Anthonomus grandis* Boh.), etc. It is therefore normally a beneficial mite, but unfortunately it also attacks man, producing a very disagreeable dermatitis.

While the male mite is very tiny, just about visible to the naked eye, the female when pregnant becomes enormously swollen, measuring nearly a millimeter in length, the abdomen presenting a globular appearance, the cephalothorax and appendages barely visible.

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[1] Wood, H. P., 1920. Tropical fowl mite in the United States. U. S. Dept. of Agric. Circ. No. 79, 8 pp.

Within the enlarged abdomen of the female may be found rather large eggs which hatch internally, and the young mites develop to maturity within the body of the mother before being extruded. The number of young produced by the female is said to range from a few to nearly 300.

A number of epidemics of dermatitis have been traced to these mites, infection having been brought about by sleeping on straw mattresses or while laboring in grain fields at harvest time. The infection has been confounded with hives, scabies and even chicken pox and smallpox, and appears on the neck, chest, abdomen, back, arms, and legs, in fact the whole body may be involved and the itching is very intense. The eruption is commonly accompanied with fever as high as 102° F.

According to Goldberger and Schamberg[1] the itching subsides under continuous exposure in from 3 to 7 weeks. They also recommend treating the affection with an ointment of beta naphthol, sulphur, benzoate and lard.

To destroy mites in the straw of mattresses or in other situations, fumigation with sulphur or steaming is recommended.

As to prevention Webster[2] suggests burning the grain stubble during the fall, winter or spring, also that threshing direct from the shock resulted in the control of the grain moth and consequently of the parasitic mites.

J. Flour and Meal Mites—Grocer's Itch

Family Tyrogliphidæ

Characteristics of Tyrogliphidæ—This family includes a small group of very tiny mites, ordinarily about 0.5 mm. or less in length. Several of the species attack grain, flour, meal, dried meat, hams, dried fruits, insect collections, etc. Their development is so rapid that there may be literally millions of them in some stored product in a few days.

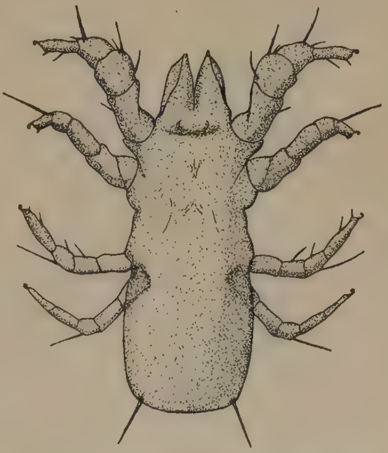

Fig. 214.—A stored food mite or flour mite, *Tyroglyphus (Aleurobius) farinæ* (male). × 145.

The metamorphosis of this group involves a peculiar stage known as the *Hypopus*, appearing after the larval and nymphal stages, very

[1] Goldberger, J., and Schamberg, J. F., 1909. Epidemic of an articariod dermatitis due to a small mite (*Pediculoides ventricosus*) in the straw of mattresses. U. S. Public Health Reports, Vol. 24, No. 28, pp. 973-975.

[2] Webster, F. M., 1910. A predaceous mite proves noxious to man. U. S. Dept. of Agric. Bu. of Ento. Circ. No. 118, 24 pp.

unlike either of these and very different from the adult. This stage is said to attach itself, non-parasitically, to flies and other insects, which serve as disseminators of the mites.

Persons handling stored products, cereals, flour, meal, etc., may be attacked temporarily by the mites, causing severe itching and irritation of the skin, known as "grocer's itch."

Tyroglyphus siro Linn. is the cheese mite, also found in grain and stored products; *T.* (*Aleurobius*) *farinæ* De G. (Fig. 214) is known as the flour mite and is common in flour mills and granaries; *Tyroglyphus longior* Gerv. attacks grains, cereals, dry seeds, etc.

No doubt the best way to destroy mites occurring in stored products and the like is to subject them to a dry heat of 130° F. for at least half an hour.

K. Red Spiders

Family Tetranychidæ

Characteristics of Tetranychidæ.—To this family belong the "web-spinning mites," most commonly infesting vegetation and destructive to fruit trees and other plants. The term "red spiders" is ordinarily applied to the group. *Tetranychus bimaculatus* Harvey attacks many species of plants as does the common red spider *T. telarius* (L.).

Persons employed in picking hops and harvesting almonds, etc., often complain of itching produced by the red spiders, but this soon disappears.

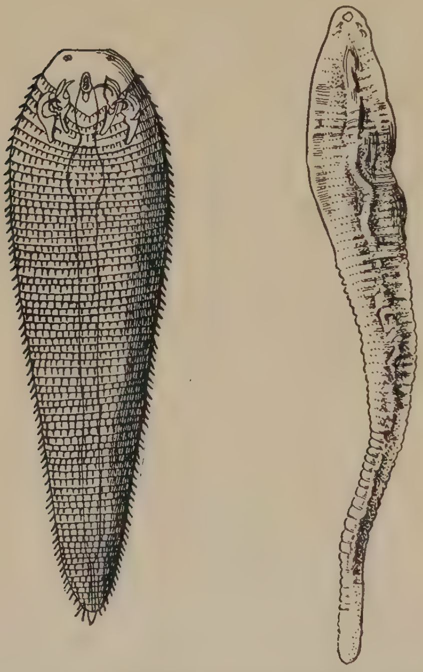

FIG. 215.—*Linguatula serrata*, larva, left; adult, right. (Redrawn after Brumpt.)

Linguatulids or Tongue Worms

Order Linguatulina

Tongue worms resemble the acari in some respects but are rather more commonly considered under a separate order, *Linguatulina*. They are devoid of feet, vermiform and annulated, their respiration is cutaneous and intermediary hosts are necessary in their development. They may reach a length of from 3 to 5 inches when fully mature. In the adult stage they inhabit the nasal passages, tracheæ and lungs of carnivorous mammals and reptiles while the larvæ live in the viscera of certain other animals which may serve as food for the former. The eggs are discharged from the nostrils and mouth of the infected animal and ingested by the intermediary host with food and water.

The tongue worm of the dog is *Linguatula rhinaria* (Pilger) = *Linguatula serrata* (Fröh.) = *Pentastoma tænioides* Rud. (Fig. 215). It inhabits the nasal cavities of the host (dog, wolf, fox and occasionally man), where it reaches a length of from 8 to 10 cm. (Brumpt). The intermediary hosts are likely to be sheep, goats, rabbits, etc. The species is comparatively rare.

The genus Porocephalus is represented by *P. crocodili* Wheeler of the crocodile (*Crocodilus americanus*), and *P. armillatus* (Wym.) of the python.

CHAPTER XX

VENOMOUS INSECTS AND ARACHNIDS

Insect Venoms.—Insect venoms, like other animal venoms, are toxic principles probably not greatly unlike the bacterial toxins, but about which we know comparatively little. Unlike the bacterial toxins which reach injurious amounts after a period of incubation subsequent to the introduction of the corresponding bacteria into the body, the venoms on the contrary act almost instantly, i.e., as soon as introduced.

The venoms act in one or more ways when introduced into the body: (1) they may act directly as solvents on the blood corpuscles (*hemolytic*); (2) they may act directly on the nervous system producing a shock or inhibiting reflexes (*neurotoxic*); (3) producing an infiltration and congestion of blood (*hemorrhagic*) often in the vicinity of the wound or deeper tissue, such as the mesenteries, etc. A given specific venom may produce one or more of the above conditions.

As has been discovered by various investigators and as is a matter of common observation, repeated inoculation of minute or attenuated quantities of a venom may lead to a degree of immunity, so also with venoms or poisons of bees, bedbugs, mosquitoes, fleas, cone-noses, etc.

In the ants, bees and wasps (aculeate hymenoptera) there are two poison-secreting glands, one of which produces *formic acid* and the other an *alkaline* fluid. The combination of the two agents in certain proportions is evidently necessary to produce the reaction of a bee sting.

The scorpion (an Arachnid) secretes a large quantity of colorless acid-reacting liquid soluble in water and heavier than the same. According to Calmette, less than 0.0005 gm. from *Buthus afer* Leach will kill a white mouse in about two hours.

How the Venom is Introduced.—Venoms of insects in a broad sense are introduced into the bodies of animals in one of three ways: (1) by *contact*, e.g., irritating hairs of certain caterpillars, such as the brown-tail moth (*Euproctis chrysorrhœa* Linn.), producing a condition similar to nettling, or the vesicating fluids of the blister beetles (Meloidæ), particularly *Lytta vesicatoria* Linn.; (2) by the *bite* or thrust of a piercing proboscis, as in the cone-noses (Reduviidæ), or pierce of the cheliceræ of spiders; (3) by the *sting*, as in the bees or wasps (aculeate Hymenoptera) and the scorpion. The operation and structure of stings varies considerably, notably in the examples cited.

Irritating or Nettling Hairs.—A rash known as the "brown-tail rash" is traceable to the caterpillar of the brown-tail moth (*Euproctis* *chrysorrhœa* Linn.), a common and very destructive shade tree pest in Europe and in America, especially New England. When the caterpillars of this species molt, myriads of tiny barbed hairs are shed with the skin. When dry these hairs are blown about by the wind and coming in contact with the skin of the face or hands produce a very severe dermatitis. The hairs are hollow and it has been shown by Tyzzer that they contain a definite poisonous principle which is injected into the circulation by the sharp-pointed hair in contact with the skin, thus producing the rash.

Blister Beetles.—Blister beetles belong to the family Meloidæ (= Cantharidæ) (Order Coleoptera) and are so designated because of their vesicating properties, i.e., the application of the pulverized bodies of many species, if not all, produces a blistering of the skin. The most notable example of the Meloidæ is the Spanish fly, *Lytta vesicatoria* Linn. (see Chap. VI).

The Meloidæ (= Cantharidæ) are described by Comstock, viz.: "The blister beetles are of medium or large size. The body is comparatively soft; the head is broad, vertical and abruptly narrowed into a neck; the prothorax is narrower than the wing covers, which are soft and flexible; the legs are long and slender; the hind tarsi are four-jointed, and the fore and middle tarsi are five-jointed."

The blister beetles deposit their eggs on the ground, the larvæ are active and feed it is said in some species on the eggs of locusts and solitary bees, others are predaceous. They undergo a number of changes not usual to insects and their development is consequently termed hypermetamorphosis. The adults are vegetable-feeding.

VENOMOUS INSECTS

Cone-noses or Kissing Bugs, belonging to the Fam. Reduviidæ (see Chapter VIII), are most commonly concerned with the more painful "bites" inflicted by insects. Their mouth parts (see Chapter IV) are beautifully adapted to piercing the skin or covering of the host. The Reduviids are essentially predaceous, attacking many species of insects, particularly plant lice and other soft-bodied forms from which they suck the body fluids. Attack upon humans is made principally, if not wholly, in self-defense. Persons picking up boards, sticks or stones, etc., may accidentally also pick up one of these insects, or in plucking a leaf or flower from a tree or other plant the fingers may close upon the insect as well, with the result that a very painful bite is almost invariably inflicted.

The principal offenders are about 18 to 20 mm. in length and all bear a general resemblance to the illustration (Fig. 216). Among the important species in their relation to human comfort are the following: *Opsicoetes* (*Reduvius*) *personatus* Linn., known as the "kissing bug";

Conorhinus sanguisuga Lec., the "blood-sucking cone-nose" or "big bedbug"; *Triatoma protracta* (Uhler), the "China bedbug"; and *Rasahus biguttatus* Say, the "two-spotted corsair."

The symptoms produced by *Triatoma protracta*, the usual culprit in California, are decribed as follows: "In a few minutes after a bite the patient develops nausea, flushed face, palpitation of the heart, rapid breathing, rapid pulse, followed by profuse urticaria all over the body. The symptoms vary with individuals in their intensity."

The symptoms described for *Rasahus biguttatus* are as follows: "Next day the injured part shows a local cellulitis with a central spot; around this spot there frequently appears a bulbous vesicle about the size of a ten-cent piece and filled with a dark grumous fluid; a smaller ulcer forms underneath the vesicle, the necrotic area being generally limited to the central part, while the surrounding tissues are more or less swollen and somewhat painful."

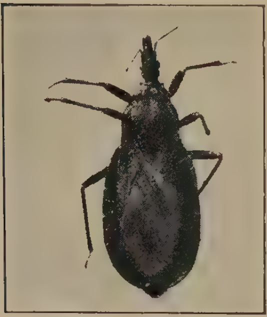

Fig. 216. A typical blood-sucking cone-nose, *Triatoma protracta*. × 2.

Treatment for Cone-nose Bites is discussed in a previous chapter (Chapter VIII).

Bedbugs (Fam. Acanthiidæ = Cimicidæ), **Fleas** (order Siphonaptera) and **Mosquitoes** (Fam. Culicidæ), all inflict bites of greater or less severity, depending on individual cases. To many persons the bite of any one of the above proves benign, while to others even one bite may prove very irritating. Frequently the severity of a bite is traceable to an infection induced by undue scratching with the finger nails. Ordinarily the itching may be relieved by the application of ammonia. For a discussion of each of the groups the reader is referred to the respective chapters dealing with the same.

THE BEE STING—STRUCTURE AND OPERATION

The Bee Sting.—For precision exhibited in minute parts and for accuracy of operation, the sting of the honeybee (*Apis mellifera* Linn.) stands unsurpassed among the weapons of defense and offense carried by insects. From the barefoot boy that plays in the flower-dotted meadow, to the philosopher delving in the mysteries of a locust blossom at close hand, the sting of the bee demands instant respect. Cheshire has nicely stated the matter thus: "Man and bees alike live in a world where good and evil grow together, where the thrift of the industrious excites the cupidity of the idle. Let us then, accepting the sting without regret, strive to learn the way in which, for us, it shall cease to be an evil."

Morphology of Sting.—Accepting the sting as a specialized ovipositor the worker bee, or aborted female, must be used. The sting can be easily extracted either by separating the segments of the abdomen from it by means of dissecting needles, or by squeezing the live bee between forceps, which pressure causes it to protrude the sting. The sting can then be grasped with other forceps and drawn out. After extraction, the sting can be best examined when the parts are floated out in a few drops of glycerin.

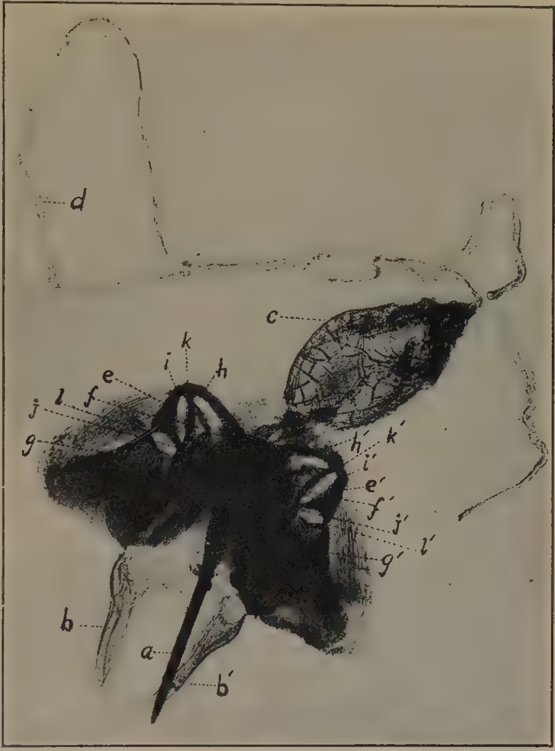

Fig. 217.—Sting of a honeybee (*Apis mellifera*). *a*, the two serrated darts; *b*, *b'*, sting palpi; *c*, venom (poison) sac; *d*, venom gland; *e*, *e'*, triangular plates or levers; *f*, *f'*, semilunar plates or levers; *g*, *g'*, lateral plates or levers; *h*, *h'*, y-shaped darts; *i*, *i'*, points of attachment for darts to levers; *e*, *e'*; *j*, *j'*, points around which levers rotate; *k*, *k'*, points of attachment for levers *f*, *f'*. × 17.5.

For purposes of description the sting may be divided into three parts, viz.: the piercing apparatus; the lateral plate and appendages; the poison sac and glands.

The piercing apparatus itself consists of three parts, one the so-called sheath, the other two lying within the sheath, and partially surrounded by it. In appearance the sheath is yellowish and translucent. The darts, which present concave surfaces to one another, are highly chitinous. The distal one third of the dart possesses a series of sharp barbs, whose shape has been aptly compared to the tip of a crochet needle. Cheshire states that each dart has from three to six barbs, other writers seem doubtful as to the number. The careful observations of the writer in which many barbs have been examined give no instance in which it was impossible to distinguish *ten* barbs on the outer edge of each dart (Fig. 217). Several writers state that poison pores are to be found at the base of each barb, from which poison exudes. In this matter, experience forces the writer to agree with Snodgrass in his remark that thus far he has failed to observe the exit of poison elsewhere than between the darts at their tip.

Proceeding upward on the dart from the tiny barbs, the darts are seen to form a figure Y as they lie within the sheath. The arms of the Y gradually bend laterally. The plates attached to the upper edges of these laterally bent arms will be described under the next heading. One of the most remarkable portions of the darts is the poison valve with which each is provided. At the point of separation, the darts each present a delicate cup-shaped valve, whose closed portion is directed downward toward the tip of the sting. This is formed of the same chitinous material which composes the darts, and each is free to move with the movement of the dart. In order to accommodate this enlargement of the darts, the sheath at this point expands to about five times its smallest diameter, which is at the tip of the sting. For at least one third of its length the sheath at this portion is expanded into a symmetrical oblong body providing ample room for the movement of the darts and valves within.

A curious structure, said by many writers to be found on the sheath, consists of two delicate, but strong, chitinous tracks or guide rails on which the darts, correspondingly grooved, fit and move back and forth. Since the sheath does not sufficiently surround the darts to direct their course, this guide-rail system which Carlet has observed, and which is accepted by other authors, offers a pretty and probable solution of the reason for the smooth and accurate play of the darts within the sheath.

Lateral Appendages.—The lateral appendages are of three kinds, viz.: semilunar, triangular and lateral, according to shape or position. Both the semilunar and triangular plates are attached to the bent ends of the Y-shaped darts. The triangular plates are attached to the arms of the darts almost at their extremities, while the semilunar ones are connected for about one third of the distance from the ends of the arms. Permitting this comparison of the smallest of the plates to a triangle, although the comparison is not an exact one, the explanation of its position may be continued by saying that the apex of the triangle is that portion which is attached to the extremity of the dart. The other two points then point outward and downward, and serve as points of attachment for two elevated edges on the lateral plates which hang thus suspended. As they hang, half of their surface lies above and covers the dorsal surface of the semilunar plates just beneath them. Continuing in the same straight line with the semilunar plates and attached at their extremity to them, lie the fleshy palpi covered with delicate hairs. This outline description of the position and attachment of movable plates will be supplemented in the explanation of their mechanism, where they can be more readily understood through their function.

Venom Sac and Glands.—The third set of structures which completes the sting is the venom sac and glands. In order to understand these, it is necessary to know that Hymenoptera are divided into two groups, those which kill their prey by stinging, and those which only paralyze it. The former are the most complicated for they possess two poison glands. One, the formic acid gland, which opens directly into the great poison sac, is the larger of the two. The other, the alkaline gland, which is comparatively small, is situated at the base of the poison sac. It is the combination of the formic acid and alkaline fluids from the two glands that results in the death of the attacked insect, or that causes the extreme irritation in humans.

The formic acid gland alone is found in those Hymenoptera, which only paralyze their prey when stung. This fact has led various observers to make chemical tests of both the formic acid and alkaline substance. The result, according to Carlet and others has been to show that neither substance by itself is effective except to paralyze, but when combined the substances have deadly effects upon other insects. Carlet's experiments to prove this were made upon house flies and blow flies by injecting each substance singly and then introducing both into the body of a fly. The results are entirely convincing.

Operation of the Sting.—After considering the very complicated structure of this minute instrument of attack and defense it will not be surprising to find, perhaps, that the mechanism of its parts is even more complicated and at the same time so wonderfully accurate that human invention can only look and marvel.

The microscopic structure of parts makes an examination of the mechanism extremely difficult. Also the stubbornness which characterizes a bee when it would be persuaded to sting without the usual incentive, adds to the problem of studying the operation of the sting. An effort was made to see the sting in operation by confining the bee on its dorsal side and then prodding it until its sting was angrily thrust in and out. This process showed three things, viz.: that the sharp-pointed sheath was always first to appear when the thrust was made; second, that the darts inside the sheath worked back and forth alternately, and quite independently of the sheath or of one another; third, that the poison was exuded in droplets from the tip of the sting between the darts. Beyond these points, observation of the mechanism of the sting was impossible, but the description of Cheshire's observations gives a very clear and plausible explanation.

> "The sheath has three uses: first, to open the wound; second, to act as an intermediate conduit for the poison; and third, to hold in accurate position the long-barbed darts. The sheath does not inclose the darts as a scabbard, but is cleft down the side which is below, when the sting points backward. The darts, as soon as their ugly barbs establish a hold, first one and then another drive back and forth by successive blows. These in turn are followed by the sheath, when the darts again plunge more deeply,

until the murderous little tool is buried to the hilt. But these movements are the result of a muscular apparatus yet to be examined. The dovetail guide-rails of the sheath are continued far above its bulbous portion, and along with these the darts are also prolonged upward, still held to the guides by the grooved arrangement; but both guides and darts, in the upper part of their length, curve from each other like the arms of the Y, before mentioned, to points C, C' (Fig. 215) where the darts make attachment to two levers (i, i'). The levers, or plates, as they are called (Kl and $K'l''$), are provided with broad muscles, which terminate by attachment to the lower segments of the abdomen. These, by contraction, revolve the levers aforesaid round the points f, f', so that without relative movement of rod and groove, the points c, c' approach each other. The arms of the Y straighten and shorten, so that the sheath and darts are driven from their hiding place together and the thrust is made by which the sheath produces its incision and fixture. The sides being symmetrical, we may, for simplicity's sake, concentrate our attention on one, say the left in the figure. A muscular contraction of a broad strap joining K and D (the dart protractor) now revolves k on l, so that a is raised, by which clearly c is made to approach d; that is, the dart is sent forward, so that the barbs extend beyond the sheath and deepen the puncture. The other dart, and then the sheath, follow, in a sequence already explained, and which G is intended to make intelligible, representing the entrance of the sheath, b the advance of the barbs, and c the sheath in its second position. The barb retractor muscle is attached to the outer side of i, and by it a is depressed and the barbs lifted. These movements, following one another with remarkable rapidity, are entirely reflex, and may be continued long after the sting has been torn, as is usual, from the insect. By taking a bee under the microscope and forcing the sting into action, the sting movement will be seen to be kept up by continued impulses from the fifth abdominal ganglion and its multitudinous nerves, which penetrate every part of the sting mechanism and may be traced even into the darts. These facts will show why an abdomen separated many hours may be able to sting severely, as I have more than once experienced."

Sting in Situ.—It can readily be seen that the sting originates from the seventh and eighth segments and lies between the oviduct and the rectum above. The darts of the sting follow the ventral line of the abdomen and are held in place by the sheath situated just above, while the barbs of the darts are pointing downward and outward. In a space above the sheath lie the fleshy palpi. The delicate attachment between the sting and the organs of the abdomen is here indicated, for only a small portion of the sting, in comparison with its size, has any connection with parts in the abdomen. This accounts for the ease with which the sting is torn from the abdomen when the barbs become imbedded after a thrust of the darts is made.

Stinging Insects.—The stinging insects belong to the order Hymenoptera, suborder Aculeata, and are best known as the ants, bees, and wasps, in which the females of all species are provided with a specialized ovipositor known as a sting, more or less well developed for piercing the skin of higher animals or other insects. The sting is used either as an organ of defense or offense, in the latter case often to procure food for the young.

The principal aculeate Hymenoptera are divided into the following superfamilies: viz.: Formicina, the true ants; Sphecina, the digger wasps; Vespina, the true wasps; and Apina, the bees.

The superfamily Formicina includes the true ants, which are divided into three or more families, Formicidæ, Poneridæ, and Myrmicidæ. One of the most formidable stinging ants in California is *Pogonomyrmex californicus* Buck. This ant will not only attack humans but also smaller domesticated animals. Thus hog raisers in the Imperial Valley, California, report many pigs killed by ants, one farmer reporting a loss of 400 small pigs during one year and another 100 to 150 during a period of three years,—all killed by ants.

Ants of this species are very abundant in the Imperial Valley, and it is a matter of common observation to see a small pig walk leisurely upon an ant mound and suddenly begin to kick and squeal, due to the terrific attack of the myriads of ants rushing forth from the nest. The writer has meager experimental evidence to deny the popular opinion above stated. The pig is certainly very uncomfortable during the attack, but experimental evidence of paralysis and death due to the ants has not been secured. However, much more work needs to be done to safely deny the statements of practical hog raisers.

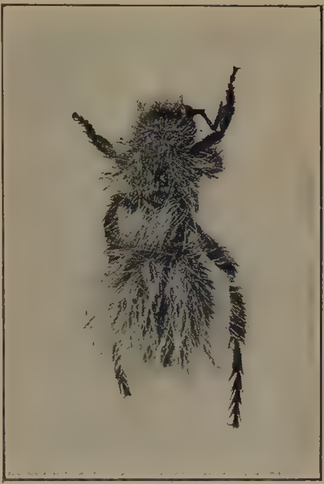

Fig. 218.—A velvet ant (Mutilla), also known as a "cow killer." × 2.2.

The ants may be destroyed by applying kerosene to the nests, using a funnel or hollow rod to reach the deeper parts; potassium cyanide in liquid form may also be used, but great care must be exercised both in the preparation and application of the same owing to its very poisonous nature.

Among the Vespina, the best-known stinging species belong to the family Mutillidæ, the velvet ants, also known as the woolly ants, cow killers, etc. (Fig. 218). The velvet ants are covered with hair and the body is commonly banded with two or more strongly contrasting colors. There are very many species of Mutillids, most of which measure from ½ to 1 inch in length. A very common species in the central states of the United States is *Sphærophthalmia occidentalis* Linn., a black species with a scarlet band. This species is very common on the beach sands of Lake Erie, causing bare-foot bathers much distress.

Many of our large dusty yellow to cinnamon colored species belong to the genus Mutilla and are commonly called "cow killers" (Fig. 218). These occur abundantly among dry leaves along the roadside or bypaths in the woods.

To the Vespina also belong the yellow jackets or hornets, *Vespa maculata* Linn., and other species which build large nests in the branches of trees, also the mud daubers, *Pelopœus cementarius* Drury, *Polistes pallipes* Lep., and *Polybia flavitarsis* Sauss., *et al.* These species with their relatives belong to the family Vespidæ, and all have a well-developed sting which may be used on the least provocation.

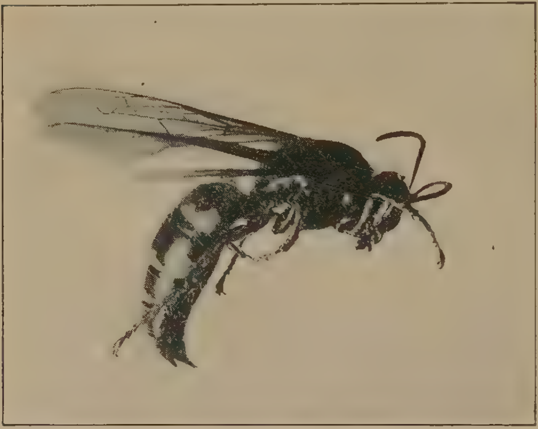

Fig. 219.—A digger wasp (*Sphecius speciosus*). × 1.1.

Of the solitary wasps belonging to the superfamily Sphecina, the great digger wasp or "cicada killer," *Sphecius speciosus* Say (Fig. 219), is the most formidable. This species, a member of the family Bembecidæ, is nearly an inch and a half in length, is black with yellow segmentally arranged partial bands on the abdomen. This wasp easily brings to earth very large cicadas, carries its prey to a previously prepared burrow where eggs are deposited and the larvæ develop in the cicada.

Underground wasps' or hornets' nests may be treated successfully with carbon bisulphid, while sulphur fumigation or thorough spraying with kerosene will suffice to destroy the nests of wasps built in the branches of the trees. Night treatment is suggested.

The true bees belong to the superfamily Apina, the honeybee *Apis mellifera* Linn., a member of the family Apidæ, and the bumblebee *Bombus fervidus* Fabr. and others belonging to the family Bombidæ.

SPIDERS

Class Arachnida—Order Araneida

Characteristics of the Araneida.—All spiders belong to the order Araneida in which the abdomen is sac-like and unsegmented, joined to the cephalothorax by a slender pedicel. According to Comstock[1]

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[1] Comstock, John Henry, 1912. The Spider Book. Doubleday, Page & Co. xv + 731 pp.

the cheliceræ are usually claw-like, "folded back into a groove in the basal segment, like the blade of a pocketknife into a handle," i.e., *uncate;* or they may be pincer-like (*chelate*), "there being a prolongation of the first segment which is opposed to the claw." The pedipalps are more or less leg-like. The four pairs of legs are all fitted for walking. There are usually present eight eyes but these may be reduced to six, four, two or none. The respiratory organs of spiders are either *book lungs* or *tracheæ,* or in most species a combination of the two. The book lungs are sacs which open on the ventral side of the abdomen by means of slit-like spiracles. Within each sac there is a series of lamellate folds. The tracheæ are far less developed than in insects and are much more localized.

The Araneida are divided into more than thirty families.

Spider Venoms.—All spiders secrete venom by means of which they kill their prey. The venom glands are located in the anterior portions of the cephalothorax and are two in number. "Each gland discharges its product through a long slender duct which opens near the tip of the claw of the chelicera of the corresponding side of the body. This opening is so placed that it is not closed by the pressure of the bite, but allows the venom to flow into the wound. In the tarantulas each gland is situated in the basal segment of a chelicera. The glands are sac-like in form; the lumen of the sac serves as a reservoir of venom; the wall is composed of excreting cells, supported by a layer of connective tissue, and there is a layer of muscle fibers surrounding the sac" (Comstock).

While spider venom is very destructive to the life of insects upon which spiders prey, there is little evidence (with certain exceptions) to indicate that this venom is injurious to man. Most of our so-called spider bites are traceable to other sources, particularly cone-noses (Reduviidæ). Comstock (1912, *loc. cit.*) has given much attention to this matter and has come to the conclusion that there are no spiders that need be feared in the northern part of the United States at least, and in the South there is only one dangerous genus, *Latrodectes.* As to the so-called tarantula (Heteropoda) which is brought to the North in bunches of bananas Comstock has the following to say: "This, however, although a large spider is an inoffensive one. Mr. John T. Lloyd informs me that he has collected scores of specimens of this species with his hands in Samoa, where it is abundant, and has never been bitten by it."

The Hourglass Spider (*Latrodectes mactans* Fabr.), also known as the "black widow" or "shoe button" spider, is a medium-sized, glossy black, naked spider. The females measure from one to one and a fourth inches in length over all, while the males are less than an inch in length. The abdomen is globose, marked ventrally with brick-red triangular spots (Fig. 220). These spots vary in arrangement,—often two of these touch base to apex, or apex to apex, not unlike an hourglass in outline, or there may be four, roughly arranged like a Maltese cross; in some individuals only one spot may be seen. The males and immature females are variously striped and spotted with lighter markings. The species belongs to the family Theridiidæ.

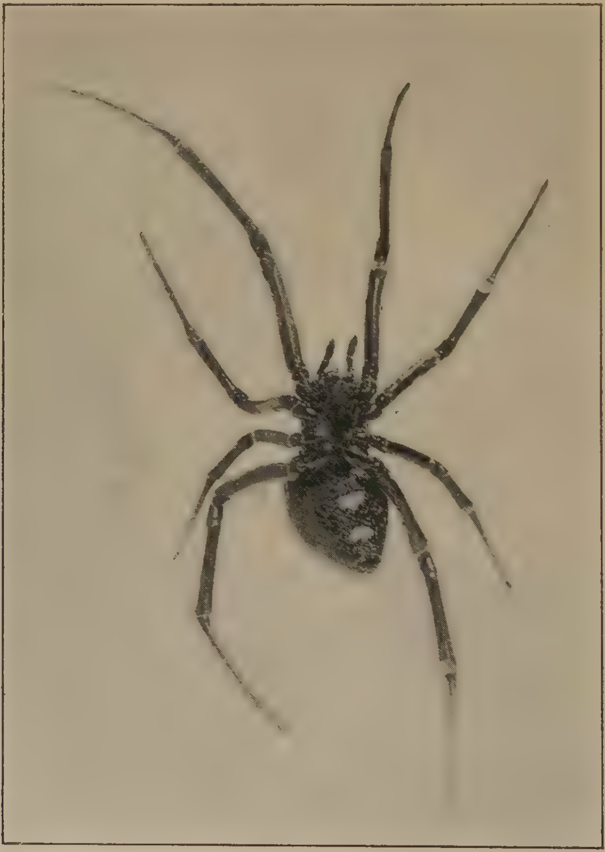

FIG. 220.—A venomous spider, *Latrodectes mactans.* × 3.

Latrodectes mactans Fabr. occurs quite commonly in California and the southern United States, also the West Indies, Madagascar, New Zealand, Northern Africa (Algeria) and South America (Peru), and has the reputation of being extremely venomous. Many specimens have been collected by the writer at various times in both the Sacramento and San Joaquin Valleys (California) and occasionally reports of its having caused dangerous and even fatal illness have come to his notice, but unfortunately very little experimental evidence seems to be available. Baerg[1] has recently reported an experiment in which he allowed this species to bite him on the inner surface of the basal joint of the third finger of the left hand, and although he suffered much pain and was bedridden and the attending physician states that the poison is more slowly eliminated than that of a rattler, yet the experimenter writes that "the effects are not likely to be serious."

An account of a fatal case in North Carolina is given by Packard and Howard,[2] viz.: An employee (farm laborer engaged in hauling wood) of Mr. John M. Dick is reported to have been bitten by a black spider with a red spot on it at about 8:30 o'clock A. M., dying of the effects about fourteen hours later, i.e., between 10 and 11 o'clock P. M. The victim is said to have felt something crawling on his neck, and as he brushed it off it bit him very severely, causing very great pain. The cause was described as being a black spider with red spots. An examination of the neck revealed ten little white pimples, all of which could be covered with a one-dollar silver coin; no puncture was seen. There was no swelling, but the neck, left breast and arm were so hard that no impression could be made with the thumb. The man complained of pain running through his entire body. It should be noted that the man was perfectly healthy. By 1 o'clock the pain had settled in his bowels and shortly thereafter he was attacked with spasms. About 4 o'clock spasms recurred and the patient lapsed into unconsciousness and remained so until death.

Kellogg[3] reports the description of a case by Dr. Coleman, viz.:

> "Patient B. came to my office one morning at 8:15 o'clock, showing signs of acute poisoning of some sort.
>
> "The glans of the penis had been bitten by a spider while the patient was sitting in an outcloset. The only thing felt was a sharp sting. (The spider was captured so there is no doubt as to the species; it was a female of *Latrodectes mactans.*) In about ten minutes there appeared dizziness and weakness of the legs, followed by cramps in the abdominal muscles.
>
> "The patient left the field where working and started to walk to town, a distance of a little over a mile. The pains grew worse and the penis started to swell and turn red. When the office was reached, the pains, of a cramp-like character, in the abdomen, were intense, also around the heart and thighs. Physical examination showed the heart to be running at the rate of 40 per minute, of small volume but regular. The respiration was labored. The pupils were dilated and face very red and congested. The penis was swollen to a great size, fully 3 inches in diameter at the glans, and the color was a mottled purple. The contractions were clonic in character, giving the greatest pain in the chest and abdomen. There were no pains below the knees or elbows.

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[1] Baerg, W. J., 1923. The effects of the bite of *Latrodectus mactans* Fabr. Journ. of Para., Vol. IX, No. 3, pp. 161-169.

[2] Packard, A. S., and Howard, L. O., 1899. A contribution to the literature of fatal spider bites. Insect Life, Vol. 1, No. 7, pp. 204-211.

[3] Kellogg, V. L., 1915. Spider Poison. Journ. of Para., Vol. 1, No. 3, pp. 107-112.

"The treatment consisted of hypodermic injections of strychnin 1/40, followed in ten minutes by nitroglycerin 1/100. Local applications to the side of bite of the crystals of potassium permanganate. The heart went to as low as 27 beats to the minute. After three hours' work, using repeated injections of strychnin, the heart-rate was increased to 45. The pains were not quite so severe and the patient was taken home. The administration of strychnin was stopped and the use of brandy hypodermically was substituted, a dose of 10 mm. being given every hour. Heat was applied to the feet and back. At 5 p. m., or about nine and one-half hours after the first symptoms, the heart-rate had been raised to 55 and then as the pains were still severe, a ¼ morphin with 1/150 atropin was given. The pains eased up and the patient dropped to sleep.

"The next morning a fine rash appeared all over the body, accompanied by some itching. The penis had returned to nearly normal in size. The heart-rate was 60, the respiration 18 and deep, temperature 100. The rash disappeared in four days. The patient was troubled with insomnia for several days, and a stubborn constipation that took a very active purge to affect."

That there is present in the body and poison gland of certain spiders a powerful hemolysin known as "arachnolysin" is proved by the experiments of Sachs as cited by Kellogg (*loc. cit.*). The diadem spider (*Epeira diadema* Walck.) contains enough poison to destroy completely all the corpuscles in 2.5 liters of rabbit blood. While arachnolysin can be preserved in glycerin for months in full strength of effect, it is easily destroyed by heat; exposure to 70° to 72° C. for forty minutes destroys it wholly.

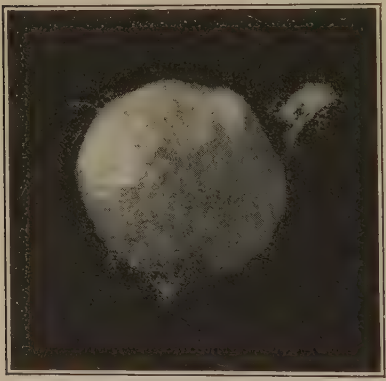

FIG. 221.—Egg cocoon of *Latrodectes mactans.* × 2.

According to Comstock (1912, (*loc. cit.*), Merriam (1910) in "The Dawn of the World, Myths and Weird Tales told by the Mewan Indians of California," the Northern Mewuk says: "Po'ho-noo the small black spider with a red spot under his belly is poison. Sometimes he scratches people with his long fingers, and the scratch makes a bad sore. . . . All the tribes know that the spider is poisonous and some of them make use of the poison." The latter states also that the California Indians rank this spider with the rattlesnake as poison, and mash the spider to rub the points of their arrows in it.

Habits and Life History of *Latrodectes mactans* Fabr.—This spider occurs, when in its geographical range, not uncommonly in old outbuildings, particularly privies, old barns, stables, woodpiles, under low wooden and concrete bridges, culverts, etc. It spins a rough web in which it catches its prey, mainly flies and other insects. It is an exceedingly aggressive species, as the writer has observed in the several grown individuals under observation at various times in the laboratory. The egg cocoons (Fig. 221) are spun during the summer, and are well protected by the web and carefully guarded by the female. Each egg cocoon contains three hundred, more or less, rather large eggs. The incubation period in observed cases at a maintained temperature of 27 ± 1° C. was about thirty days,—for example a spider spun her egg cocoon during the night of July 17, the eggs hatching during the night of August 13. Seven egg cocoons were spun by one spider, but the eggs contained in the seventh did not hatch. The writer has observed the spinning of egg cocoons as late as September 20.

The young spiders (Fig. 222) are gray, quite unlike the adult in this respect, and are very active, attacking plant lice, etc., at once. The first molt takes place within a week, followed by numerous molts at intervals of a week or more. The young spiders grow darker with each molt, with the appearance, however, of creamy white lines or spots dorsally on the abdomen. The reddish ventral markings appear within a month ordinarily. Growth is very rapid during the rest of the summer and autumn, but maturity is not reached until the following spring or early summer.

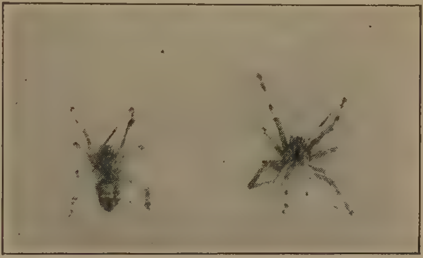

Fig. 222.—Young stages of *Latrodectes mactans.* Left, ventral view, showing reddish hourglass-like marking on abdomen; right, dorsal view, showing white abdomen with dark markings. × 3.

Treatment for Latrodectes Bite.—The successful treatment of Latrodectes bites for a number of reported cases has been a local application of a supersaturated aqueous solution of permanganate of potash every two hours. Escomel advises also, internally, a teaspoonful of a solution of permanganate (1 to 4,000) every three hours with milk diet. Escomel also recommends this treatment for the bite of *Gliptocranium gasteracanthoides* Nicolet the "pruning spider" of Peru which he considers even more dangerous than Latrodectes.

Kellogg (*loc. cit.*) reports that Sachs succeeded in producing a highly effective antitoxic serum by treatment of the blood of guinea-pigs with arachnolysin; 0.0025 cc. of this antitoxin serum is sufficient to protect 0.05 cc. of rabbit blood from an otherwise hemolyzing dose of arachnolysin.

Tarantulas.—The term *tarantula* is applied to the very large spiders belonging to the Family Aviculariidæ occurring in California and other tropical and subtropical climates. The best-known species in California are *Eurypelma* (*Mygale*) *hentzii* Girard, also known as a bird spider, and *Eurypelma californica* Auss., the California "tarantula." While these spiders are much dreaded there is little or no evidence to warrant this fear. The common trapdoor spider of California is *Bothriocyrtum californicum* Cambridge, also greatly feared by many persons. Two species of beautiful garden spiders (orb weavers) are commonly regarded with great fear, namely *Miranda aurantia* (Lucas), an orange colored species, and *Argiope argentata* (Fabr.), the silver orb weaver. Both are harmless.

The term *tarantula* was first applied to an European species, *Lycosa tarentula* Linn. which according to Comstock does not belong to the spiders to which this term is applied in America.

To the bite of *Lycosa tarentula* is referred the hysterical disease known as *tarantism* said to have been common in southern Europe in the Middle Ages.

The following account of *tarantism* is taken from the Cambridge Natural History, Vol. IV, p. 361:

> "The bite of the spider was supposed to induce a species of madness which found its expression—and its cure—in frantic and extravagant contortions of the body. If the dance was not sufficiently frenzied, death ensued. In the case of survivors, the symptoms were said to recur on the anniversary of the bite. Particular descriptions of music were supposed to incite the patient to the excessive exertion necessary for his relief; hence the name 'Tarantella.'
>
> "In the middle ages epidemics of 'tarantism' were of frequent occurrence and spread with alarming rapidity. They were seizures of an hysterical character, analogous to the ancient Bacchic dances, and quite unconnected with the venom of the spider from which they took their name. The condition of exaltation and frenzy was contagious, and would run through whole districts, with its subsequent relapse to a state of utter prostration and exhaustion. The evil reputation of the Tarantula appears to have exceedingly little basis in fact."

Venomous Ticks

Class Arachnida, Order Acarina

Ticks producing local or systemic disturbances by their bite alone are known in both families, Ixodidæ and Argasidæ (see Chapter XVIII), though more commonly in the latter.

Ordinarily little or no injury results from the mere bite of an Ixodine tick,—the writer has known of *Dermacentor occidentalis* Neumann and *Dermacentor variabilis* Say to remain attached to a person for days without causing great inconvenience and occasionally quite unobserved by the host. However, Nuttall (1911, *loc. cit.*, p. 133) records a number of cases cited by other authors in which the bite of *Ixodes ricinus* Linn. has caused serious consequences, notably a case described by Johannessen of a "boy where the tick's body was removed but the capitulum remained embedded in the skin at the back of the head. Swelling followed at the point of injury, accompanied by headache, stiffening and cramps in the muscles of one side, partial loss of memory and polyuria; the pupils became dilated, etc. The boy made a slow recovery." Blanchard is quoted by the same author as stating "that accidents of a grave character occasionally follow *ricinus* bites, the wound serving as a center from which infection may spread to the rest of the body."

Quite a number of species included in the Family Argasidæ are known to cause more or less serious consequences by their bites, notably *Ornithodorus moubata* Murray, *O. coriaceus* Koch, *O. talaje* (G.-M.) and *O. turicata* Franço.

Ornithodorus moubata Murray (see Chapter XVIII) has been reported repeatedly as causing marked consequences by its bite. Wellman as quoted by Nuttall (1908, *loc. cit.*, p. 98) "states that the bite is very painful, the swelling and irritation (especially in Europeans) not subsiding for days. The wheals are hard, raised and swell most disagreeably if scratched, and this even a week after being bitten. The bite of young ticks (nymphæ) is said by the natives to be more severe than that of the adults."

Ornithodorus coriaceus Koch.—This species occurs in the more mountainous counties of California, namely Santa Clara, San Benito, Stanislaus, Monterey, Santa Barbara, Los Angeles and probably San Diego, thus connecting up with Mexico which is its original habitat. The writer has collected it on Mount Hamilton where it flourishes in the deer beds among the low scrub oaks (*Quercus dumosa* Nutt.). The following description of the species is a translation by Nuttall from the original:

> "Shaped like the sole of a shoe, thick margined, roughly shagreened, yellowish earthy color, spotted rusty red, legs toothed dorsally. Length 9.3 mm. Body about twice as long as wide, width fairly uniform, indented on the sides, pointed above the mouthparts, rounded posteriorly, a thick turned-up border all around; the whole surface above and below thickly granulated like fish skin (shagreen), the granules flat above, consequently, the whole leathery, on the back unequal folds and grooves. Beneath in the front of the body a deep groove running to the stigmata and on the inner protrusion the rather large round quite clearly marked eyes. The coxæ gradually thicken toward the distal extremity and are somewhat bent; the other articles somewhat compressed and clearly notched or round-toothed. The whole surface, above and below, dirty yellowish earthy color, rusty red spots irregularly distributed throughout. Capitulum and palps light yellow. Legs gray-brown. Female. Habitat: Mexico."

The Pajaroello is more feared than the rattlesnake by the natives and many harrowing tales are told regarding the loss of an arm or leg, or even death resulting from the bite of it. Much of this is gross exaggeration, however. Dr. W. L. Chandler, formerly a graduate student in the University of California, has given the writer an accurate account of two bites which he suffered while stationed in the San Antone Valley (California). The first bite was received July 2, 1912. He experienced a sharp pain on the left arm and upon rolling up his sleeve discovered a large tick, partly engorged, attached to the upper arm in front. He dislodged the tick and sucked the lesion. The lesion when first discovered showed a small dark purple ring surrounding a bright red spot, the point of attachment. The discoloration disappeared in a short time, but the arm was "highly irritable for two or three days and at the point of attachment a minute clear scab formed.". The tick proved to be a "pajaroello."

The second bite took place July 16 while seated in a thicket of willows (the first bite took place while riding over a brush-grown hill), and in this case the sharp pain involved the left leg. An almost fully engorged tick (again a pajaroello measuring about ¾ of an inch in length and about ½ inch in width was removed from just above the shin. Once more a bright red spot was visible at the point of attachment, surrounded by an irregular purple ring about ¾ of an inch in diameter. In about an hour the leg began to swell in the vicinity of the lesion, and in about three hours the entire lower leg was tremendously swollen. The coloration about the point of attachment had widened considerably, was puffy and a clear lymph exuded freely from the lesion. The young man lanced the leg, causing the blood to flow freely, and treated the wound with crystals of potassium permanganate, binding the leg with cotton and gauze. During the following night he reports experiencing a general disagreeable feeling, the entire lower leg "irritable and numb." On the following day the bite on the arm became irritable again, and was treated as had been the leg, fearing bad results. For several weeks both lesions exuded a clear lymph from beneath an "oily-looking, transparent, red mottled scab" which remained in evidence for two or three months.

Chandler reported these ticks very numerous in some localities, having counted as high as six within half an hour crawling over a saddle blanket placed on the ground. Their presence and number seemed to be determined by the presence of cattle, although ticks were found where there were no cattle but in places which were evidently favorite haunts of large wild animals.

Experiments with the Pajaroello.—A number of specimens of *Ornithodorus coriaceus* were collected in the San Antone Valley and at Newman, California, for purposes of experimentation and study of life history. In coöperation with Dr. W. A. Sawyer and Messrs. S. W. Newman and W. L. Chandler, the writer conducted a number of experiments particularly with reference to the bite. In one of these experiments a mature female tick (*Ornithodorus coriaceus*) was permitted to bite a nearly full-grown monkey (*Macacus rhesus*) twice with an interval of sixteen days intervening between the two bites. The tick was applied at 9:42 A. M. December 10, 1913, and began sucking blood at 9:43, one minute later, becoming engorged and falling off at 10:21 A. M., a period of 38 minutes. At 10:30 a few minutes after the tick dropped off there appeared a deep red hemorrhagic area 2 mm. in diameter at the point of biting with a somewhat lighter area 10 mm. in diameter surrounding the central area. At 10:27 there was a black spot at the point of bite 1.5 mm. in diameter, the inner red hemorrhagic area measuring 4 mm., with a yellowish white area surrounding this 8 x 6 mm., and an outer red petechial area 15 x 13 mm. No general symptoms were noted. As shown in Fig. 223 the lesion reached its greatest expanse the following day when the following measurements were taken:—dark purple spot 2 mm. in diameter (a very dark red scab); the inner red area 6 x 5 mm., the yellowish white area 20 x 12 mm., the outer area 48 x 23 mm. and fading. The yellowish white

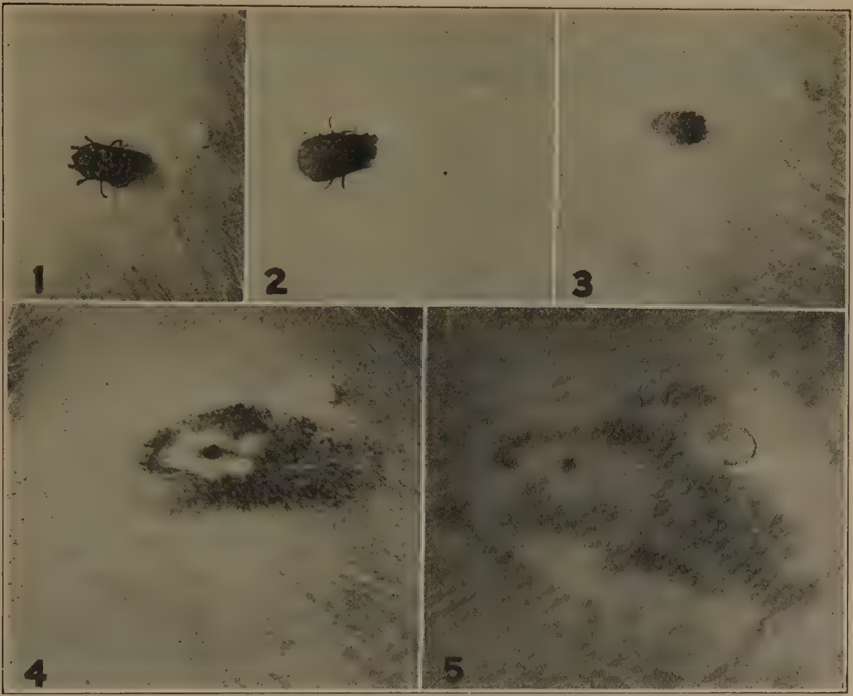

FIG. 223.—Showing venomous tick (*Ornithodorus coriaceus*) and lesion produced by same on skin of a monkey. (1) tick on skin before attaching; (2) tick attached and fully engorged; lesion appears as dark shadow at anterior end of tick; (3) shows lesion within a few minutes after tick has dropped off; (4) lesion at expiration of five hours; (5) lesion at expiration of twenty-four hours. (For description and extent of areas see text.) × .7.

area including bite was slightly swollen. By December 14, i.e., four days after the bite was received, the ecchymosis had entirely disappeared; by December 16, six days after the bite, the lesion was entirely gone but for a slight pigmentation, a thickened reddish area measuring 5 x 3 mm. and a small scab 2 mm. in diameter.

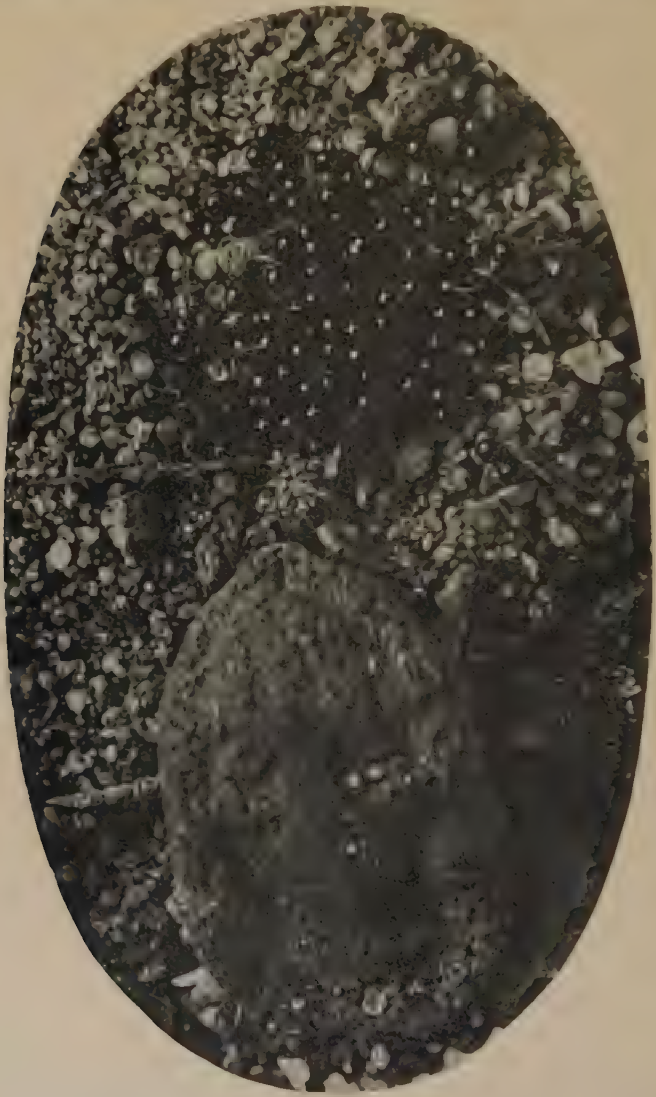

FIG. 224.—Showing *Ornithodorus coriaceus* just backing away from her eggs recently deposited in the sand. Note the protective coloration of the tick. × 5.

The monkey remained normal throughout the experiment as regards temperature, weight, blood count and general condition.

The second bite was received by the same animal on December 26, the tick being applied at 9:43 A. M., taking hold at 9:44 A. M., and dropping off fully engorged at 9:55 A. M., requiring but 11 minutes to engorge. The history of the second bite follows that of the first very closely, except for the extent of the lesion, which was greater, i.e., 70 x 31 mm. In order to note any manifestations on the part of the first lesion, the second bite was located near the opposite nipple. No change was observed. The lesion produced by the second bite had disappeared by December 31, i.e., five days after the bite, except for a slight thickening 3 mm. in diameter and a slight white scale at the center. Again the monkey had remained normal, except for a slight increase in the count of white blood corpuscles which rose from 7,400 at the time of the bite to 13,900 by noon of the same day, going down again to 7,300 by 5 P. M.

Both nymphs and adults readily attach to man, monkey, rabbit and mouse; and become fully engorged in from 15 to 30 minutes, depending on the number and length of rests in the rhythmic motion of the basis capituli. If dislodged while engorging, they, like the larvæ, refuse to reattach immediately.

On rabbits: The bite on a rabbit's ear leaves a comparatively large, thick, purple nodule, and is accompanied by a more or less hemorrhagic condition of the entire ear tissue. The bite has no apparent systemic effect on the rabbit, and the lesion heals within two or three weeks.

On mouse: When a tick was applied to the body of a mouse for the first time, the mouse showed no apparent uneasiness until the tick attempted to withdraw its head. Beginning immediately after the tick dropped from the mouse there occurred a small swelling which exuded lymph, rapidly grew in proportions and was accompanied by marked ecchymosis. In 2 minutes after the tick had dislodged itself the swelling had increased its area 0.3 by 1 cm., in 30 minutes 0.5 by 2 cm., and in one hour 0.5 by 2.5 cm. After 24 hours the swelling had become reduced, except in the vicinity of the bite, and fully one half of the mouse was dark blue. But slight systemic disturbances were noticeable in the mouse, and it rapidly recovered. The same mouse was used as a host for other ticks, and each succeeding bite produced less and less noticeable results, until finally only very slight lesions were produced.

Life History of *Ornithodorus coriaceus*.[1]—The pajaroello deposits large plum-colored spherical eggs (Fig. 224). In the laboratory these are deposited on the sand in slight depressions. There are commonly four to seven layings at intervals of from several days to several weeks during the months of May to July, inclusive (as early as February under laboratory conditions), and the female is known to deposit eggs for at least two successive seasons. The greatest number of eggs observed at one laying was 802, with a total of 1,158 for one season. The incubation period at a maintained temperature of from 24° to 26° C. is from 19 to 29 days, with an average of about 22 days.

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[1] Herms, W. B., 1916. The Pajaroello Tick (*Ornithodorus coriaceus* Koch.) with special reference to life history and biting habits. Journ. of Para., Vol. 2, No. 3, pp. 137-142.

The larvæ (Fig. 225) are very active, scattering quickly and attaching readily to a host, particularly rabbits. Experimentally the human has also served as a larval host. The ear of a rabbit apparently affords a most satisfactory point for attachment. The larva remains attached to the host for a period of about seven days, becoming quite globular and much enlarged.

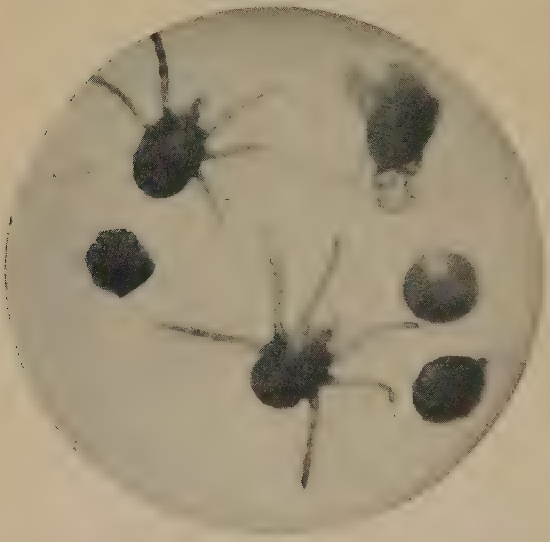

Fig. 225.—Showing egg of *Ornithodorus coriaceus* and larvæ of the same in the act of emerging; also two fully emerged individuals. × 14.

Under favorable conditions the tick becomes sexually differentiated after the fourth molt, requiring about four months to reach this stage. Others have not become sexually differentiated with five molts. Ordinarily the tick molts once for each engorgement, but there may be two molts between feedings.

Even though sexual differentiation is accomplished during the course of one summer, there seems to be little evidence at present that there is more than one generation per year.

Fully developed adult ticks were brought into the laboratory September 21, 1913, having been in captivity in the same stage four months previous and were still active and eager to bite January 1, 1915, a period of about 20 months. No molts had taken place during this time, notwithstanding the fact that full engorgement had occurred repeatedly and many eggs had been deposited.

Remedies for Tick Bites.—For the bite of *Ornithodorus moubata*, Wellman (in Ms. according to Nuttall, 1908) "recommends prolonged bathing in very hot water, followed by the application of a strong solution of bicarbonate of soda, which is allowed to dry upon the skin.

He states that this treatment is comforting. For severe itching he advises smearing the bites with vaseline which is slightly impregnated with camphor or menthol. Medical aid should be sought when complications arise."

Scorpions

Class Arachnida, Order Scorpionida

Characteristics of the Scorpionida.—The most striking characteristics of the scorpions are, first, the formidable pedipalps terminating in strong lobster-like chelæ; second, the long tail-like postabdomen terminating in a bulbous sac and sting (Fig. 226).

"The cephalothorax is compact and unsegmented; the abdomen is broadly joined to the thorax . . . consists of seven segments, and a slender tail-like division, the postabdomen or cauda, consisting of five segments. . . . The cephalothorax bears a pair of eyes near the middle line, the median eyes, and on each side near the cephalolateral margin a group of from two to five, the lateral eyes. A few scorpions are blind. . . . Scorpions breathe by means of book-lungs, of which there are four pairs, opening on the lower side on the third to the sixth abdominal segments. . . . The sexes of scorpions differ in that the male has broader pincers and a longer postabdomen. Scorpions do not lay eggs, the young being developed within the mother; after the birth of the young, the mother carries them about with her for some time, attached by their pincers to all portions of her body. . . . Scorpions live in warm countries. They are common in the southern portion of the United States, but are not found in the North. They are nocturnal, remaining concealed during the day, but leaving their hiding places at dusk. . . . They feed upon spiders and large insects, which they seize with the large chelæ of the pedipalps and sting to death with their caudal poison sting" (Comstock).

The order Scorpionida is divided into six families of which there are four in the United States, separated according to Comstock (1912, *loc. cit.*), viz.:

A. Only one spur at the base of the last tarsal segment of the last pair of legs, and this is on the outside. . . . . *Scorpionidæ*
AA. One or two spurs on each side at the base of the last tarsal segment of the last pair of legs.
  B. From three to five lateral eyes on each side.
    C. Sternum triangular; usually a spine under the sting *Buthidæ*
    CC. The lateral margins of the sternum nearly parallel; sternum usually broader than long; no spine under the sting *Vejovidæ*
  BB. Only two lateral eyes on each side. . . . . *Chactidæ*

Over three hundred species of scorpions are known, of which over sixty occur in the United States, of which the following are characteristic:

Isometrus maculatus Linn., known as the spotted Isometrus, is widely distributed in tropical and sub-tropical countries. This species is described by Comstock as follows: "A dirty yellow species marbled and flecked with black. The body is thin and slender. In the female the postabdomen is usually about as long as the rest of the body; in the male, it is often twice as long. The hand is long and thin, thinner than the tibia of the pedipalp; the finger is from one and a half to two times as long as the hand. The combs[1] have from seventeen to nineteen teeth. The female grows to nearly two inches in length; the male to nearly three inches."

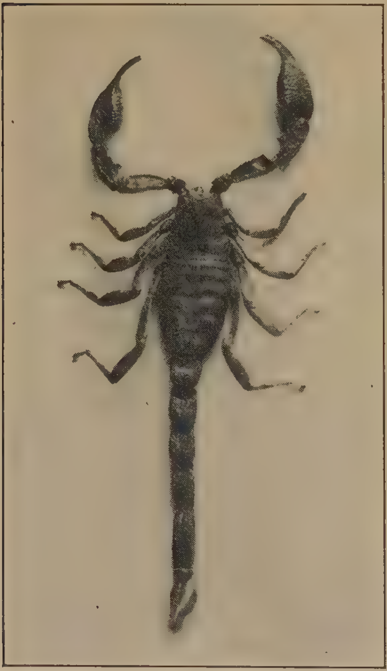

FIG. 226.—A scorpion, *Hadrurus hirsutus*. × .6.

Buthus carolinianus Beauv. possesses a spine or tubercle under the sting; body striped with black and yellow; a small pale median spot on the anterior border of the cephalothorax; legs pale yellow; post-abdomen pale. Occurs in the Southern states. (Comstock.)

Hadrurus hirsutus Wood is a very large and hairy species found in the southeastern United States. The penultimate tarsal segment of the first three pairs of legs is furnished with long hairs on the back (Comstock). The writer has taken it in the Imperial Valley (Calif.).

Uroctonus mordax Thorell, a small dark species, is very common about the San Francisco Bay region.

Scorpion Sting.—The "aculeus" or sting of the scorpion is located terminally on the final bulbous segment. The bulbous segment incloses a venom-containing vesicle connected with the sting which terminates in a hollow needle-like point. The sting curves downward when the "tail" is extended, but upwards and forwards when the scorpion poises for attack or defense, the entire tail-like postabdomen being curved dorsally and forwards. The victim is struck quickly and repeatedly, the thrust being made quite near the head of the scorpion.

Scorpion stings are quite common in California; ordinarily most persons pay no more attention to the sting of a scorpion than to the sting of a wasp. The pain produced is instant and quite penetrating. In some instances the wound is quite severe and systemic disturbances may result. Fatal cases rarely if ever occur. Fatal results are attributed to two north African species, namely *Buthus maurus* Linn. and *B. quinquestriatus* H. & E.

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[1] The combs of a scorpion are located ventrally, originating from the "sclerite on the middle line of the body" just anterior to the first segment of the post-abdomen. Each comb, of which there are two, is provided with so-called teeth.

Treating the wound promptly with ammonia ordinarily brings relief. In serious cases serum is recommended and potassium permanganate as for spider bites.

WHIP SCORPIONS

Class Arachnida, Order Pedipalpida

Characteristics of Pedipalpida.—The Pedipalpida resemble scorpions in some respects in that the pedipalps are similar. The first pair of legs is elongated and tactile, while the last three pairs are ambulatory. The term "whip scorpion" is applied to the Family Thelyphonidæ, because the terminal end of the abdomen is provided with a long slender many-segmented appendage (Fig. 227). "Grampus" and "vinegarroon" are also common names. The species are tropical and subtropical.

The whip scorpion, *Mastigoproctus giganteus,* occurs in southern California, mainly in sandy desert places where it burrows in the sand under débris. They are commonly regarded as poisonous, although they cannot sting, but may bite. The writer has found that the natives invariably fear this creature very considerably, but knows of no evidence to justify this attitude.

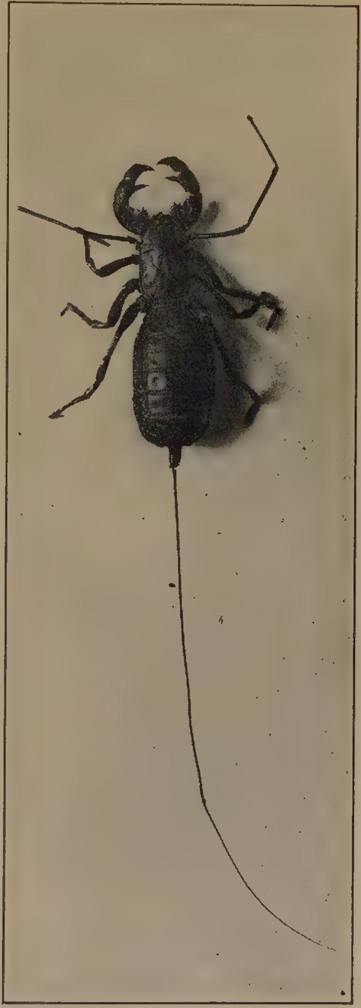

FIG. 227.—Whip scorpion (Pedipalpida) *Mastigoproctus giganteus.* × .8.

SOLPUGIDS

Class Arachnida, Order Solpugida

Characteristics of the Solpugida.—The solpugids are characterized in the Cambridge Natural History (Vol. IV, p. 423), viz.: "Tracheate

Arachnids, with the last three segments of the cephalothorax free and the abdomen segmented. The cheliceræ are largely developed and chelate, and the pedipalpi are leg-like, possessing terminal sense organs" (Fig. 228).

The general appearance is spider-like; they are very hairy, largely nocturnal, occurring in desert tropical regions. Though little is known about this interesting group, they are fairly common in certain portions of southern California, notably in the neighborhood of Salton Sea, where they are regarded as exceedingly venomous. The writer has been told that the presence of one of the animals in a watering trough would result in the death of any animal drinking from the same. There is evidently not the slightest foundation for this belief. Their bite is benign. Common names applied to this order are "Sun Spider" and "Wind Scorpion."

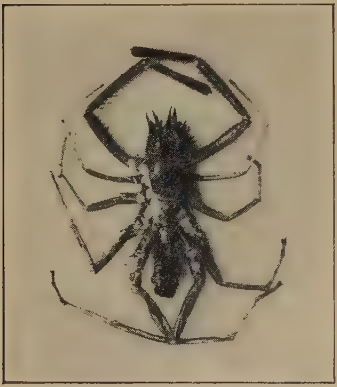

FIG. 228.—Sun spider (Solpugid), *Eremobates cinerea.* × 1.

The order is represented by a large number of species occurring only in tropical and subtropical countries, notably Africa. There are said to be only twelve species in the United States, all but one belonging to the two genera, *Eremobates* and *Ammotrecha.*

CENTIPEDES

Class Myriapoda, Order Chilopoda

Characteristics of Myriapoda.—The Myriapoda are worm-like animals with separate head, possessing antennæ, and many fairly similar segments, each possessing one or two pairs of segmented appendages. Like the insects they are tracheated and for the most part terrestrial.

The class Myriapoda is divided into four or five orders of which the following are well known, viz.: Chilopoda, the centipedes, with only one pair of appendages to each segment; and the Chilognatha (Diplopoda), the Millipedes, with two pairs of appendages to each segment, e.g., *Julus nemorensis,* a so-called "thousand-legged worm."

Characteristics of Centipedes.—The Chilopoda have only one pair of appendages to each segment and are widely separated at the bases, the antennæ are many jointed, the genital pore is located on the terminal body segment. The larger species, at least, are carnivorous, feeding mainly on insects. Notwithstanding the confusing abundance of walking appendages the centipedes crawl very rapidly.

Unlike the Millipedes, which possess no organs of defense except glands which secrete an offensive odor, the Centipedes are provided with powerful poison claws located immediately ventral to the mouth, and connected by means of a hollow tube with large poison glands.

The larger species of Centipedes belong to the following genera, viz.: Scolopendra, Lithobius and Geophilus, and may be over 6 inches in length, some are reported to be 18 inches long.

Venomous Centipedes.—The larger centipedes are commonly regarded as very venomous, and it is said that their bite may be fatal to man. It is true that an insect captured by Scolopendra or Lithobius is killed almost instantly when the poison claws close upon it.

In southern California the large greenish centipede *Scolopendra heros* Girard (Fig. 229) is greatly feared. It measures from 4 to 5 inches in length and has a very formidable appearance. It is said that it not only punctures the skin with its poison claws, causing considerable pain, but also produces a "reddish streak where it has crawled upon the body." It is interesting to know that these animals are also markedly phosphorescent, which may possibly account for some of the phenomena produced on the skin. *Geophilus electricus* and *G. phosphoreus* are notable examples of phosphorescent species.

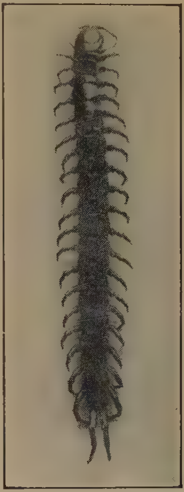

FIG. 229.—A venomous centipede, *Scolopendra heros.* × .66.

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